AVIATION IN THE NEXT MILLENNIUM

- A National R&D Plan for Improving Air Transportation Safety & Security in the 21st Century

White House Commission on Aviation Safety & Security
Task Force on Research & Development Implementation

DRAFT

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On February 12, 1997 The White House Commission on Aviation Safety and Security, chaired by the Vice President, submitted its Final Report to the President. This report presented comprehensive recommendations that portrayed a bold vision of air transportation in the coming century. The successful implementation of this vision will represent a renaissance in air travel. America will be the pathfinder, setting the world standard for aviation safety and security for the benefit of all humankind.

Importantly, many of the Commission recommendations can be implemented immediately, accelerating improvements in a national airspace system that is already the finest in the world. Many of the recommendations, however, require a longer view of how our air transportation infrastructure must evolve to meet the anticipated rapid increase in the number of air travelers. A focused and carefully managed investment strategy is urgently needed to ensure that new technologies are available when needed. This is goal of this report – to firmly set forth an R&D plan that achieves the President's goals for aviation in the coming millennium.

The research plan described herein relies on the leadership of a well-integrated Federal team, principally the Federal Aviation Administration, National Aeronautics and Space Administration, and Department of Defense. It is a team that will work closely with the private sector and academia to rapidly bring new technology to all elements of the aviation community. This plan focuses on making commercial air transportation safe and secure, but does not ignore the needs of the general aviation community. It also recognizes the critical need to integrate commercial, general, and military aircraft operations in a manner that achieves unprecedented levels of safety. Over the next five years the plan calls for more than $3.0 billion to be invested in aviation safety and security. Complementing this investment are projects being funded by aircraft and equipment manufacturers and operators aimed at goals in keeping with the Commission recommendations.

This plan is ambitious. Yet behind the investment in Federal and private funds lies a community of researchers dedicated to achieving the breakthroughs in technology that will assure our ambitious goals are met. As this century closes, I have no doubt that tomorrow's air traveler will benefit from the steps we are taking today.

Neal Lane

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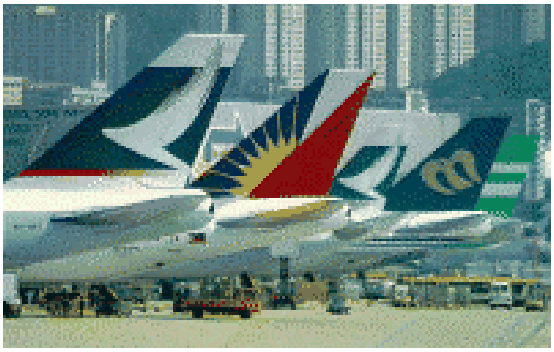
Introduction



America's economic stability and national security depends on a healthy, vibrant aviation industry. In turn, the health of aviation depends on improved levels of safety, security and traffic control modernization. As the world's leader for aviation technology, the United States has made significant contributions to assure the safety and security of the National Aviation System (NAS). The NAS is universally recognized as the safest and most technologically advanced system in the world. On a typical day, the Federal Aviation Administration (FAA) oversees more than 169,000 takeoffs and landings at airports across the nation, carrying approximately 1.7 million passengers safely to their destinations. In an average year, air traffic controllers handle approximately 141 million air carrier, commuter, short-haul, and military operations. In addition, the agency regulates the safe operation of approximately 574 certified airports, 622,261 pilots, and 450 FAA and contract air traffic control towers.

However, the nation's booming aviation network is rapidly approaching a crisis point. A Federal oversight panel and several industry reports project a dramatic increase in the numbers of air travelers within the next decade. Without changes in the capabilities of our aviation infrastructure and the methods used to control and operate aircraft, this increase in demand would carry with it a parallel increase in incidents. Also important is the increasing potential for the disruption of air service through criminal or terrorist action. The President has therefore committed to both preventing an increase in aviation-related fatalities, to a dramatic decrease in incidents, and to enhanced security for commercial flights. It is imperative that national priorities and budgets be set to promote the improvements required to meet the President's broad objectives. Many of the steps that must be taken will rely on new technology. The R&D agenda necessarily focuses on aviation-related technologies but also includes assured leadership in supporting communications, satellite, aerospace, and other technologies. Historically, major advances in safety and security have been driven by technological revolutions in aerodynamics, structures and materials, and propulsion, and by an air traffic management network facilitated by sophisticated navigation and communications systems.

The next revolution in air travel will be fueled by the continued expansion of computer and information systems. This information revolution will be as profound as the shift from open cockpits to pressurized aircraft cabins or from piston to turbojet engines. Pilots will be provided all-weather views of their flight environment and, with the advent of precision satellite navigation, aircraft will no longer be restricted to conventional radio corridors. The dawn of "free-flight" is rapidly approaching, marked by a completely digital air traffic management system that will make navigation and communication with and among aircraft dramatically faster, more efficient, and safer.

Attaining our national goals will not be possible without the introduction of new systems, procedures, and training methods developed by government scientists and engineers and their industry and academic research partners. A clear vision for achieving our national goals is spelled out in the FAA's *Safer Skies – A Focused Agenda*.[1] This FAA plan calls for broadscale regulatory reform, advanced technology solutions, and focused training programs built around a new vision of air transportation in the coming millennium. It recognizes that in an era of budget constraint, the FAA, National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD) are working together to develop a global aviation system for the 21st century. To meet these future challenges, the partnership between DoD, NASA, and FAA is employing a

[1] An electronic version of *Safer Skies – A Focused Agenda* can be found at www.faa.gov.

comprehensive research, engineering, and development program to assure all available resources remain customer-focused and targeted on the highest priority activities related to aviation safety, air traffic control modernization, and aviation security. The premise behind this coordination of R&D investments is that government can set goals, and then work with industry in the most effective way to achieve and implement them. Such interagency and industry partnerships are key to implementing a cohesive plan for improving aviation safety, security and traffic control modernization.

Background and Scope of the R&D Plan for Improving Aviation Safety and Security in the 21st Century

On August 22, 1996, President Clinton established by Executive Order 13015 the White House Commission on Aviation Safety and Security (WHCASS), which was chaired by Vice President Gore. The Commission was charged with three specific mandates: (1) to look at the changing security threat, and how to best address it; (2) to examine changes in the aviation industry, and how government should adapt its regulation of it; and (3) to look at the technological changes coming to air traffic control, and what should be done to best take advantage of them.

In it's Final Report to President Clinton, the Commission outlined how government and industry can work together to make a safe system even safer. The Report first recognized that central to maintaining the public's confidence in America's aviation system is the continued safety record of the nation's air carriers. *Fourteen* recommendations to improve safety were contained in the report.[2] The first, and most important, was the call to "reduce the fatal aviation accident rate by a factor of five within ten years." The remaining thirteen recommendations describe how that goal should be achieved. *Six* additional recommendations focused on making the air traffic control system safer and more efficient. In response to the President's first mandate, the Commission provided *thirty-one* recommendations to improve the security of America's air transportation system. Finally, though not specifically directed to do so, the Commission provided *six* recommendations on how to improve the response to aviation-related disasters. These recommendations fall into two basic categories: 1) regulatory and certification issues; and 2) research and technology issues. The regulatory recommendations are primarily directed at the FAA, where the research and technology recommendations call for DoD, FAA, and NASA to work together to improve safety.

Immediately following the release of the Commision Report, then Assistant to the President for Science and Technology and Director of the White House Office of Science and Technology Policy (OSTP), John H. Gibbons, and the Director of the White House Office of Management and Budget (OMB), Franklin D. Raines requested that DoD, FAA, and NASA work together to develop a joint implementation plan for meeting those Commission recommendations that require R&D or technology implementation[3].

This report outlines how the FAA, NASA, and DoD are working to leverage scarce resources and to establish partnerships with industry for the safety and security benefits of the flying public. It also shows how all three agencies are coordinating, planning and executing their research and development activities to maximize the return on investment for the US taxpayer. In the next section, a description of the agency roles and responsibilities in the implementation plan is briefly summarized. To remain consistent with the *White House Commission on Aviation Safety and Security's Final Report to President Clinton,* this implementation plan is divided into three sections: Aviation Safety, Air Traffic Control Modernization, and Aviation Security. In each section the agency's implementation plans are described, and a five-year budget outlay is estimated to meet those recommendations requiring R&D or technology investments.

[2] The complete WHCASS recommendations can be found in Appendix A. Commission recommendations that contain an R&D component are highlighted in bold print. The WHCASS Final Report is available in electronic form at www.aviationcommission.dot.gov.

[3] The Gibbons-Raines Memorandum can be found in Appendix B.

Building a Foundation for Safe and Efficient Air Travel - Our National R&D Goals

> "We will achieve a national goal of reducing the fatal aircraft accident rate by 80% within 3 years."

President William J. Clinton, February 12,1997

Setting the Stage - The Three R&D Goals

The Commission's recommendations provide a clear call to action within all sectors of the aviation community. This R&D implementation plan therefore is principally directed at ensuring that, (1) adequate resources are being allocated to meeting the Commission recommendations and the specific technical capabilities that must be achieved, and (2) that coordination among government agencies and between the government, industry, and academia is in harmony with this commitment.

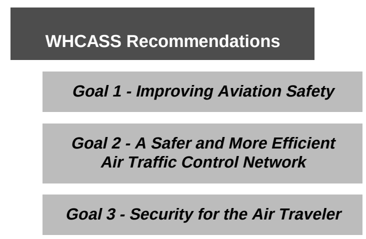


FIGURE 1: Three of the four WHCASS goals have an R&D Component

Figure 1 illustrates the three sets of recommendations that contain significant R&D components. In air safety, technological improvement is as important as new regulation and certification initiatives in meeting future goals. Safety improvements, both in the air and on the ground, will require greater investment to meet the goal that has been set. In the area of air traffic control, new practices, procedures, and systems have been under development. The Commission recommendations require accelerating the development and implementation if new capabilities are to be in-place by 2005. To combat changing and growing threats to air transportation new technologies are needed to augment the capabilities of ground personnel and to provide new means of detection and avoidance.

A three agency alliance of the FAA, NASA, and DoD is engaged in the joint pursuit of a broadly-based research and technology development effort to meet the goals outlined above. As shown in Figure 2, these agencies are committing over $600 million annually to aviation safety and security goals -- over $3.0 billion over the next five years. NASA alone has pledged to augment it's existing aviation safety program by $500 million during this period. The national investment in aviation security R&D is significant and front-loaded to make rapid improvement in the technology available to police and ground monitoring personnel. The level of investment represented in Figure 2 will likely continue past 2002 as the national infrastructure continues to improve and as highly advanced technologies are matured and implemented.

A Strategy for Implementation

The level of investment set aside for aviation safety and security R&D makes this effort a major national initiative. Driving the implementation of this major R&D initiative is an awareness of the rapid increase in demand in air transportation expected both domestically and worldwide during the next decade. As shown in Figure 3, a significant drop in accident rate is needed to avoid an increase in the number of incidents and fatalities as demand soars. The R&D plan must therefore maintain a pace that provides technology solutions in a timely fashion. Individual projects must be closely tied to operational objectives, schedules must be carefully monitored and communicated among participating organizations, and results disseminated as rapidly as possible. The

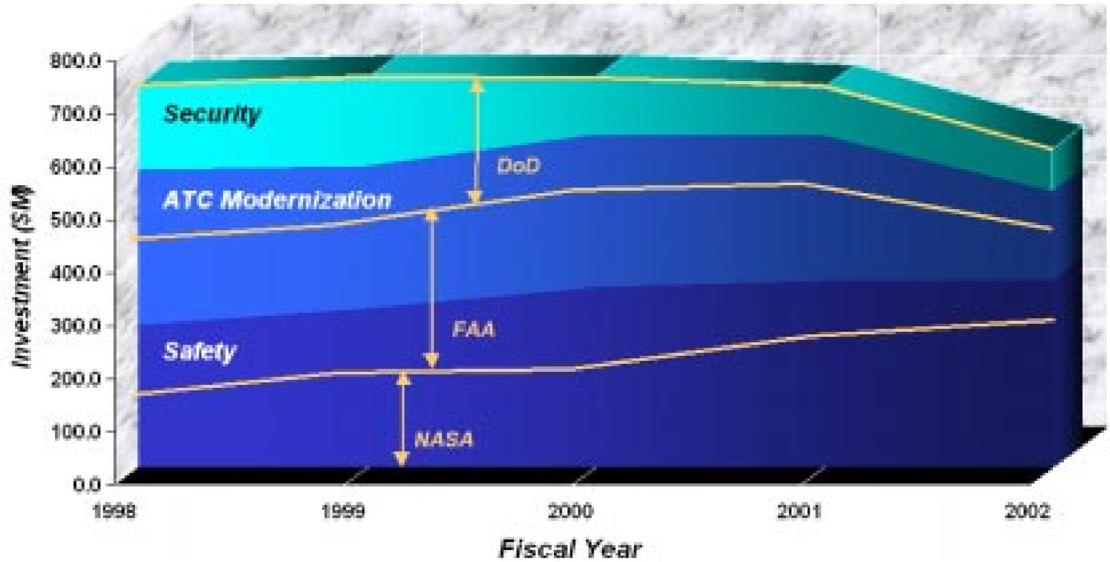


FIGURE 2: The Federal Investment in Aviation Safety & Security R&D

manufacturability and operability of new designs is also of paramount importance, necessitating the integration of equipment suppliers and subsystem manufacturers more deeply than usual into the R&D program.

To meet a challenging set of aviation safety and security goals, the FAA and NASA have joined forces in the pursuit of new technologies. Together they have developed a management structure centered around:

- Objectives, project milestones, and budgets tied to Commission recommendations and prioritized to address the most pressing concerns first.
- Performance metrics to keep projects on track, that are reported both internally and externally as part of the strategic and performance plans of the respective agencies.
- Monitoring of technology readiness and close ties with private industry, including co-investment plans that will lead to future products.

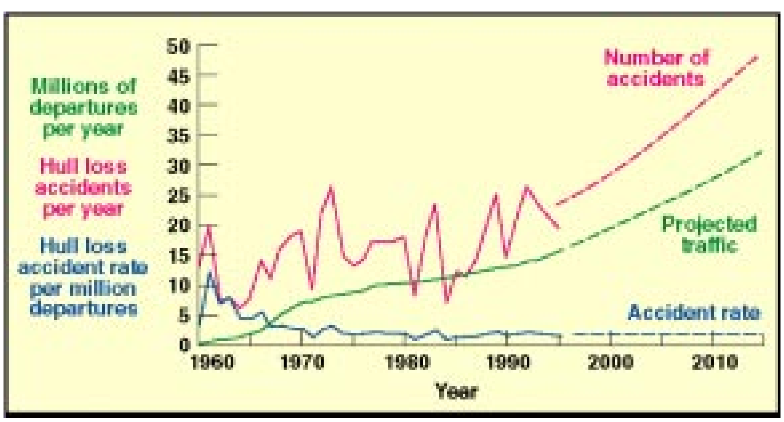


FIGURE 3: Accident rate must decline as travel demand increases

The ultimate measure of success of the aviation safety and security R&D initiative will be meeting the goal of reduced fatalities in air disasters. This ultimate metric is not sufficient, however, in terms of applicability to the planning and implementation of an R&D program. Fortunately, fatal accidents occur infrequently, but this means they are of limited use in guiding new programs. As suggested in Figure 4, far more insights are available in the vast reserves of information that describe on-going aviation operations and the numerous incidents that occur that have potential safety impact.

Interpreting and applying this information, however, relies on an understanding of the relationship between precursor incidents and how they sometimes lead to fatal accidents. Aircraft accidents are usually caused by a series of precursor elements that under certain conditions can lead to fatalities. The challenge for R&D community is to accurately identify accident precursors from the large set of incidents or from operational data such as flight data recorders. R&D efforts that explore this causal chain are, therefore, extremely important to meeting overall safety goals. In the majority of cases, human performance is the critical element in preventing, or failing to prevent, an incident from becoming an accident. This underscores the importance of human factors research as an underpinning science in aviation safety programs.

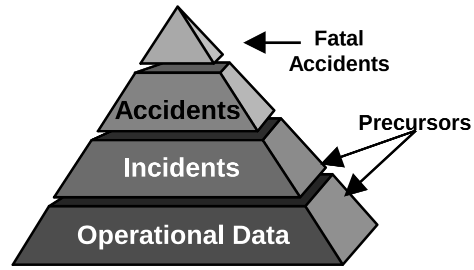


FIGURE 4: The Relationship Between Precursors and Accidents Must be Better Defined

The Cost of Safety

Improving the safety and security of air travel will not come without a price. New systems will require an investment by the airline operators and by general aviation pilots to comply with new regulations and procedures. In some cases the economic benefit of new systems may not outweigh the costs of implementing them if traditional strategies for calculating cost/benefit are followed. These investments are imperative, however, if the President's ambitious goals are to be met.

Figure 5: Enhanced GPWS warns of approaching terrain conflicts

The economic viability of air travel is also an important objective of government. U.S. carriers and the general aviation community must be presented with affordable solutions in pursuit of aviation safety and security goals. A key element of the R&D plan is, therefore, to guild the development of new technologies toward solutions that are affordable to the aviation community. Low-cost systems, such as the Ground Proximity Warning System (GPWS) shown in Figure 5 have been an important product of the R&D program.

The Federal Role – Building the Foundation

The recommendations of the White House Commission on Aviation Safety and Security require the involvement of FAA, NASA, and DoD, with a corresponding investment by each agency, as shown in Figure 6. The FAA, NASA, and DoD are committed to an integrated partnership in aviation safety focused on investing in research leading to new safety impacting technologies, and in transitioning those technologies into aviation operations.

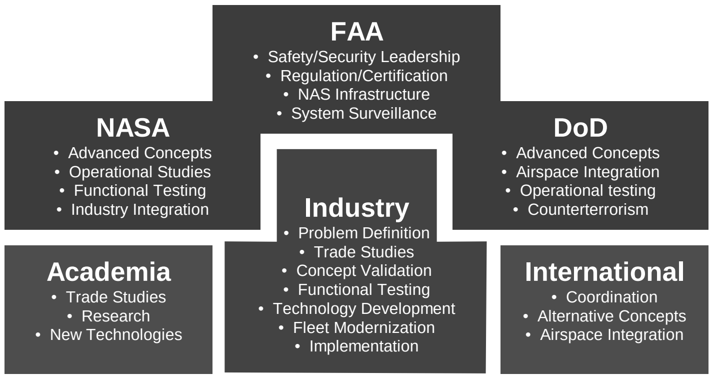


Figure 6: Advances in aviation safety and security are built upon strong partnerships between key players

The fundamental mission of the FAA is to foster a safe and efficient air transportation system. The FAA's goal is *to provide a safe global air transportation system by developing technology, technical information, tools, standards, and practices to promote the safe operation of the civil aircraft fleet.* In the areas of aircraft safety (as a result of the Aircraft Safety Research Act of 1988), the FAA has the planning responsibility for research directed towards current and future airworthiness needs, with a focus on procedures and strategies. An additional role of the FAA is to insure that the appropriate regulatory and certification issues in aircraft safety and airworthiness are addressed in inserting the technology developed by the FAA, NASA, DoD, academia, and industry. These agency goals have been reaffirmed in the FAA's *Safer Skies* initiative and the need for close interagency cooperation, along with partnership with industry, cleared stated.

NASA and the FAA have long worked together on air traffic management systems to enhance the capacity, efficiency, and safety of the National Airspace System. NASA uses its technical expertise to develop advanced air traffic decision support tools, improve training efficiency and cockpit safety through human factors research, and develop and flight test advanced communication, navigation and surveillance systems. The FAA applies its operational expertise in these same areas to ensure that the technically advanced airborne and ground equipment, software and procedures developed by NASA are operationally useful, efficient, safe and cost effective.

The Automated En Route Air Traffic Control (AERA) and the Center TRACON Automation System (CTAS) are excellent examples of the partnership between FAA and NASA in developing and transferring enabling technologies for air traffic management and control. The User Requirements Evaluation Tool (URET) is a product of AERA, and the User Preferred Routing (UPR) is a product of CTAS. The CTAS program was officially started within NASA under base R&D funding as part of the Aviation Safety and Automation Program. FAA maintained awareness of the program through the FAA's office located at NASA's Ames Research Center. In 1991, based on results of the program, NASA entered into a Memorandum of Agreement (MOA) with the FAA to jointly develop CTAS for testing at a FAA Air Traffic Control Facility. In response to many recommendations from a broad spectrum of the aviation and aerospace industry that NASA and FAA cooperation be enhanced, the FAA and NASA entered into a joint Memorandum of Understanding (MOU) at Air Traffic Management (ATM) R&D. This resulted in the National Plan for ATM R&D and an interagency team to manage that joint program. To meet the FAA's needs, NASA created the Advanced Air Transportation Technology (AATT) program. This program is committed to "...complete field demonstration of user preferred routing (decision support tools) in support of near-term free-flight implementation requirements..." and to deliver it by the end of FY97.

The FAA, NASA, and DoD have established a variety of coordinating committees that will deal with issues that cross agency boundaries. These committees are currently being used as an overarching management structure to bring research programs together across the agencies. The FAA-NASA Coordinating Committee was established in May 1980 by the FAA and NASA administrators, and renewed again in 1990, to provide a formal mechanism for FAA-NASA coordination at the executive level. Its objective is to provide a continuing executive level exchange of information between NASA and FAA concerning each agency's ongoing safety-related programs and future requirements.

Trilateral coordination between the FAA, NASA, and DoD is provided through a series of forums for executive discussion of topics of mutual interest in safety-related aeronautics research. A Memorandum of Agreement between NASA and DoD was signed in September 1988 to establish the Aeronautics and Astronautics Coordinating Board. Its mandate is to act as the senior management review and advisory body to DoD and NASA to facilitate the coordination of aeronautics safety-related activities of mutual interest. Additional organizations involved in implementing the Commission's recommendations are the National Transportation Safety Board and the National Weather Service.

The Role of Industry – Implementing Effective Solutions

The aviation industry makes critical contribution in partnership with the Federal government. Industry will help assure that major safety issues are identified and that the proposed enabling technologies designed to resolve the safety issues are affordable and practical when compared with alternate solutions. Industry will be ultimately responsible for the implementation of new technologies, and compliance with regulations and certification requirements. Throughout the research program the central theme is public-private partnership, structured to develop effective solutions as expeditiously as possible.

Manufacturers

Following the partnership theme, the Federal government must ensure especially strong ties with the community of manufacturers of aircraft and aviation-related equipment. The Commission recommendations lay out an ambitious timetable to meet near-term safety and security objectives. This requires close interaction at the implementation level for new technologies. U.S. manufacturers have embraced the goals set forth by the Commission and, in turn, are investing heavily in the successful implementation of the recommendations. The FAA, NASA, and DoD have streamlined R&D programs and created progress plans that are tightly integrated with manufacturers. This is a very important step that ensures that new concepts will mature quickly into operational systems that can be employed quickly to protect the traveling public. It must also be recognized that much of the R&D related to aviation safety and security takes place in industrial research laboratories and facilities. It is important to consider that the Federal government is not acting alone in meeting ambitious aviation safety and security goals. The private sector is making a large corporate investment in basic and applied research and the development of new products.

Operators

No less important is the role of airline operators. Though air transportation has reached a highly evolved state, new knowledge is a constant product of accident investigation and safety research. Both major and regional airline operators must continuously absorb information and quickly turn new knowledge into safer practices. In turn, airline operators are critical source of guidance to researchers, informing them of operational needs and providing practical oversight of the implications and priorities of on-going research. Preventing accidents starts with airline operators, a tremendous responsibility that highlights the importance of their role in the aviation safety and security frontier.

Industry Representatives

The advice and guidance of the many industry trade representatives is also being sought to help focus Federal R&D investments. Organizations like the Airline Pilots Association and the Air

Transport Association actively participate with Federal agencies in the joint planning of research programs and helping to identify new practices that can best employ new technologies.

The Academic Community – Establishing New Pathways

Our academic institutions will be called upon to become active research partners in identifying candidate solutions and conducting research. In partnering with research institutions across the U.S., the FAA, NASA, and DoD seek the best available expertise and the pooling of knowledge to address pressing issues. Academic institutions like the Purdue University, Pennsylvania State University, the Massachusetts Institute of Technology, and the University of Oklahoma are studying advanced methods of predicting weather and its effect of air travel. Other institutions like the University of Massachusetts and Case Western Reserve University are developing advanced materials that are less toxic and that release less heat in the event of a fire. Academic researchers are also heavily engaged in advanced propulsion R&D, aeromechanisms, and improved aerodynamics. These and many other institutions are actively engaged in a diverse R&D program to meet tomorrow's aviation safety and security goals.

Maintaining Vibrant International Cooperation

Aviation safety and security is a global issue. Aircraft are manufactured all over the world and international air travel is rising steadily. Especially important is the affect that a major accident has throughout the world, not only in terms of perceptions of the traveling public, but on the need to jointly plan and implement global solutions. As seen in Figure 7, the U.S. has one of the lowest

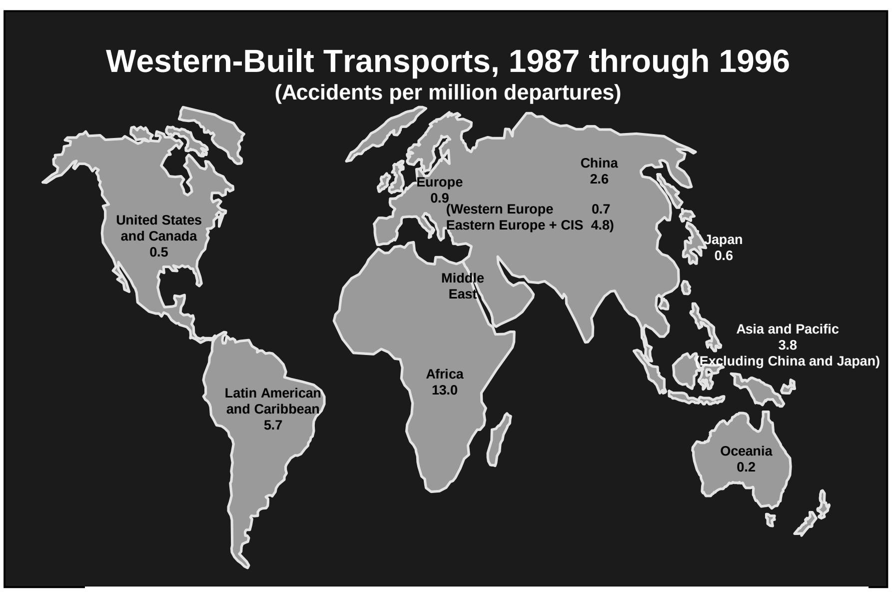


FIGURE 7: A global focus on safety endeavors to see all nations see a dramatically reduced accident rate.

accident rates in the world. The Commission safety goals for improving safety carry with them a desire to see accident rates come down across the globe. Management of the air traffic system is also a global enterprise, and many foreign governments and organizations are working cooperatively with the FAA on issues related to the safe navigation of the world's airspace.

One of the U.S.'s strongest alliances is with the European Organization for the Safety of Air Navigation (EUROCONTROL). FAA cooperation with EUROCONTROL occurs across a broad front including communications, information exchange, application of advanced radars, and the implementation of satellite-based navigation systems. Emphasis is being placed on research related to air traffic management under the new 'free-flight' concept to be implemented in the near future. The FAA also works closely with the International Civil Aviation Organization (ICAO), primarily on the implementation of satellite-based navigation, but also on new standards for aircraft separation, and air-to-ground communications. Cooperative research programs are underway with Australia, Canada, France, Germany, India, Israel, Italy, Japan, Mexico, the Netherlands, Russia, and the United Kingdom to pursue the development of new technologies and operating concepts to make the worldwide airspace system equally safe and secure.

Improving Aviation Safety - Implementing Goal 1

Sidebar: Wind Shear Avoidance – A Safety Success Story

Safety is the primary concern of everyone within the aviation community. Though air travel involves the use of advanced technology and the complex interaction of human beings it has emerged as an extraordinarily safe mode of transport. Seeking to improve aviation safety is, therefore, a goal to make something very good even better -- it is a path of continuous improvement in technology, operating practices, and decision-making. A dedication to safety requires a willingness to change our aviation systems, from the design of aircraft to the way they will ultimately will be flown and maintained. As shown in Figure 8, more that $1.6 billion will be invested in aviation safety R&D. Of this investment, 60% will be directed to reducing the fatalities of aviation accidents.

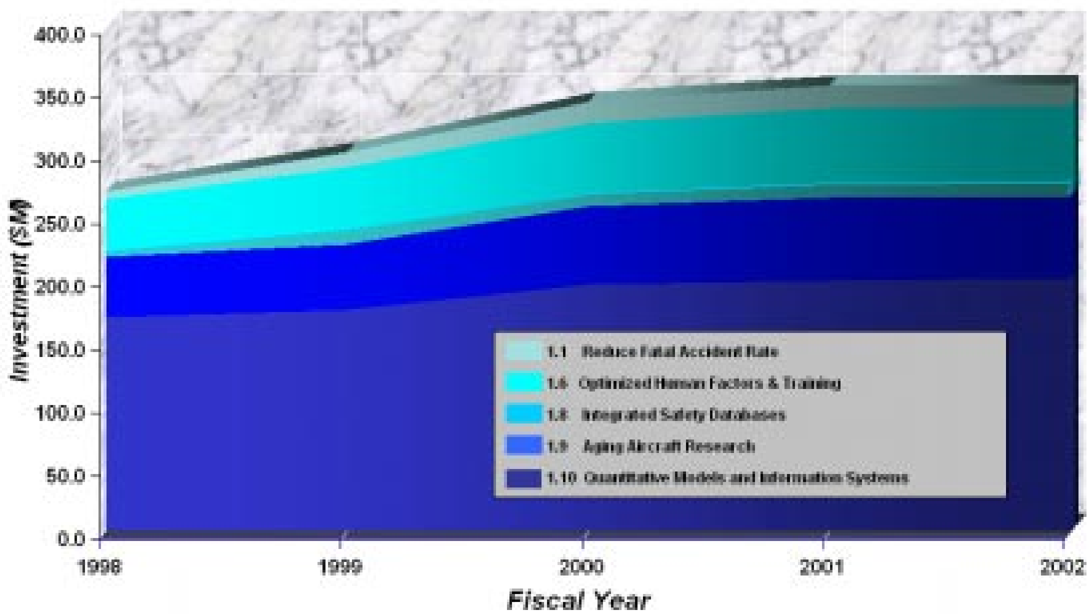


FIGURE 8: Over $1.6 billion will be invested over the next five years on research to make aviation safer.

The R&D agenda related to aviation safety is focused to make the greatest impact in areas where accidents are occurring with the highest regularity. Figure 9 presents the classes of fatal aviation accidents. The development of new technologies and operating methodologies must be prioritized to cause a reduction in those areas with the highest accident rate. Controlled flight into terrain (CFIT) is the leading cause of fatal accidents. CFIT accidents occur when pilots lose situational awareness of the flight environment, become disoriented, or cannot locate the visual cues needed to safely maneuver the aircraft. A number of new technologies are being developed to improve a pilot's awareness of both the status of the aircraft and the environment through which it is moving.

Focusing attention on eliminating the major classes of accidents is an important step, but it must also be acknowledged that additional insights are needed that more closely examine causality. Classifying an accident as a CFIT event explains "what" happened, but not "why" an accident occurred. Government and industry researchers are carefully examining accident and incident records to reveal why human and machine systems fail under certain conditions. This 'root cause' analysis is expected to reveal new ways of categorizing accidents and generate new perspectives on how to prevent them.

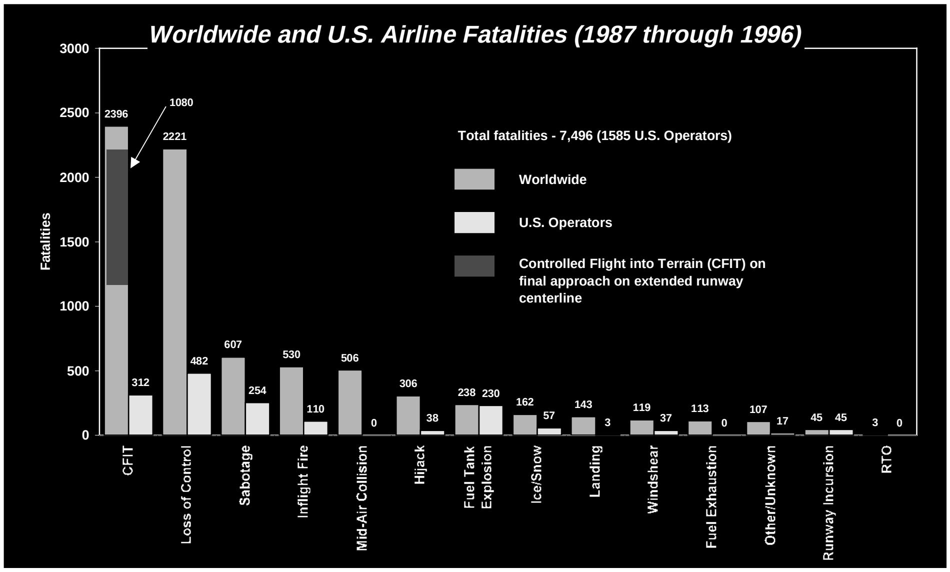


FIGURE 9: Worldwide and U.S. Airline Fatalities (1987 through 1996)

Safety requires teamwork. The government is involved in improving safety in all aspects of aviation. The FAA, NASA, and DoD have each embraced the Administration's aviation safety goal. NASA has pledged to continue R&D beyond 2007 that supports continue to reduce the accident rate. Federally-sponsored research is particularly important in developing the future systems that will reduce accident rates to near zero. The teamwork required to improve aviation safety is aptly illustrated by the case of windshear accidents (see sidebar). Windshear is a particularly hazardous condition that can quickly cause a fatal accident. Government research into windshear avoidance was prompted by fatal accidents in New York in 1975, New Orleans in 1982 and Dallas-Fort Worth in 1985. About 500 fatalities and 200 injuries had resulted from windshear crashes involving at least 26 civil aircraft between 1964 and 1985. Windshear also has caused numerous near accidents in which aircraft recovered just before ground contact. Today windshear accidents are rare and in the future they will be virtually unknown. The example of windshear avoidance illustrates well the role of R&D in flight safety and the cooperation needed between government agencies, the private sector (aircraft manufacturers, airline operators, and equipment manufacturers), and the academic community.

Theme and Investment Areas

Our Federal aviation safety R&D effort follow three principal themes and three key investment areas. The themes are the foundation on which FAA, NASA, and DoD research projects are based, they are:

> ***Fewer Accident Precursors*** -- reexamine aircraft systems, ground equipment, and operating systems and procedures to reduce the number of incidents that are known to precede fatal accidents. Significantly reducing the number of precursors will make a dramatic reduction in the likelihood of a fatal accident.

Inherently Safe Systems -- reinforce a *devotion to safety* in the design of aircraft and aviation systems and the procedures used to operate them. This requires understanding how and why accidents occur and the continuous reinforcement of lessons-learned.
Failure Tolerant Designs – building systems that can withstand failures or that can maintain a safe environment for aircraft passengers and crew when a failure occurs.

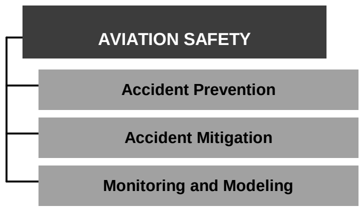


FIGURE 11: Investment in aviation security occurs in 3 areas

Federal R&D investments are focused in the three areas, shown in Figure 11. The government's primary R&D focus, of course, is on prevention. Preventing accidents involved basic and applied research into aircraft and ground systems and new operational strategies**.** *System-wide* accident prevention focuses on design principles, fatigue and performance readiness, human error metrics, training, maintenance, and information integrity. *Single aircraft* accident prevention is directed at pilot aiding, control in adverse conditions, flight critical systems, health monitoring, aging aircraft and systems, design and integration, engine failure containment, and technology integration. *Weather* accident prevention concentrates on topics in strategic weather information, turbulence, icing systems, and synthetic vision. This includes new types of flight decks to improve visibility and operational awareness, high-reliability systems that resist or withstand failure, and strategies to ensure that aircraft remain separated from each other and a safe distance from hazardous terrain and weather.

Mitigation, the second theme area, means improving the crashworthiness of aircraft so that if an accident should occur it will not prove fatal to the occupants. Mitigation technologies include fire prevention and resistance, crash-resistant structures, and evacuation systems. Finally, improved monitoring and modeling methods are a crucial aspect of the overall plan. This includes careful analysis of aviation incidents to predict safety trends and the sharing of data among agencies that control aviation safety incident and accident records. It also involves the development of new models to be used in the design and operation of aircraft.

A series of workshops were held in early 1997 to define an aviation safety strategy and establish the R&D investment strategy to achieve the Administration's ambitious aviation safety goals. Sponsored by NASA, in partnership with the FAA, DoD and the National Weather Service, the workshops formed the basis of what has become the Aviation Safety Investment Strategy Team (ASIST). The ASIST process comprised five teams - Human Error Consequences, Weather, Flight Critical Systems & Information Integrity, Human Survivability, Aviation System-wide Monitoring, and Modeling & Simulation. ASIST has helped to identify and prioritize aviation safety issues, ensure information sharing among participants, and preclude duplication. Most importantly the ASIST effort has created a prioritized list of investment options to provide solutions to the national safety needs.

Accident Prevention

The principal elements of the Federal R&D investment in aviation safety are described below. The goal of Federal R&D programs related to aviation safety is to develop and test technologies that will prevent accidents before they occur. While the majority of R&D concentrates on commercial aviation, it by no means excludes the general aviation and military aviation communities. The future will see greater interoperability between general, commercial, and military aircraft and safety in each domain is essential if overall safety goals are to be met.

Human Factors

Human actions are a leading cause of accidents. Increasing automation is, however, not necessarily the most appropriate means of achieving safety. Human factors research seeks to identify true improvements in how humans interact with all elements of air transportation. Technological solutions are sought that improve the ability of pilots, ground controllers, technicians, and support personnel to operate equipment safely and to respond effectively when an anomaly occurs.

In 1995 a *National Plan for Civil Aviation Human Factors* was published with FAA, NASA, and DoD as signatories. This plan was the result of broad-based cooperation within the aviation community and recognized the increasing importance of human factors research in the safe operation of the national airspace system. R&D is continuing under the plan. At NASA efforts are focused on cockpit automation, crew fatigue, team decision-making, and air-ground communication. DoD is concentrating on crew response in high workload situations, fatigue, and decision-making research. FAA researchers are focusing on human-centered cockpit automation, new criteria for evaluating and selecting personnel, training, performance assessment, and bioaeronautics – a science to improve crew and passenger performance and safety through physiological integrity. Government research initiatives are closely tied to industry developments in the field of automation, training, and performance assessment. Annual outputs are expected to continuously improve the state-of-the-art in these technology areas.

Flight Safety and Control

Loss of control is the second leading cause of aviation accidents. When an anomaly occurs the ability of the human operator and aircraft systems to retain control is critical if accidents are to be avoided. In cooperation with the FAA, industry, and academia, NASA's Intelligent Damage Adaptive Control System (IDACS) program is pursuing research to development alternative means of controlling an aircraft with a damaged flight control system. The program is examining ways of using engine thrust to control aircraft and the development of self-repairing flight control systems. New designs will be flight-tested on NASA aircraft, with a goal of a demonstration flight on a commercial transport in the 2003 timeframe. DoD is conducting related research on alternative control systems for aircraft in response to system failures.

NASA's Total Aircraft Management Environment (TAME) program aims to better integrate aircraft control systems so that pilots are able to achieve optimal performance under all flight conditions. A pilot's ability to maintain control during adverse conditions will be augmented if a higher level of integration of aircraft flight control systems can be achieved. Other NASA and DoD advanced flight control R&D will lead to systems designed to resist pilot induced oscillations our other erroneous inputs to flight control systems. Tolerance to error is another design goal of advanced control concepts. Future systems will be more resistant to single and multiple failures.

Incident and accident data show that crew response to an engine failure continues to be a major safety concern. In 2000 the FAA will initiate research with industry to examine the emergency responses of crew members in a simulator. In the near-term this research will lead to improved operating procedures for existing aircraft, but in the future new designs are expected that will more tolerant of engine failures and that assist the crew in making appropriate responses.

FAA research continues to refine the surveillance and collision avoidance algorithms used in the traffic alert and collision avoidance system (TCAS) II avionics. The agency plans to continue to resolve operational issues related to TCAS II implementation and to gather incident data in support of other aviation safety initiatives.

Advanced Aircraft Structures

The FAA's aircraft structural integrity research and development activities, for example, increase aviation safety by reducing the likelihood of fatalities and injuries resulting from structural failures in commuter, rotorcraft, and transport aircraft. To prevent aircraft structural failures, agency researchers are developing aircraft inspection systems and techniques capable of the early detection of material degradation, such as cracks, corrosion, and debonding. As composites play a more important role in aircraft structures, the FAA is conducting research to better understand the effects of repeated loads, damage, and joint repair on these materials.

NASA' Advanced General Aviation Transport Experiments (AGATE) program is working to advance the state-of-the-art for light aircraft. Under the auspices of the AGATE program the FAA is working with NASA to develop a composite properties data base. This research is linked to a cooperative program between the FAA and the U.S. Army to refine testing handbooks with new data to better characterize current and emerging composite materials.

Aging Aircraft

A 1997 National Research Council Report, "The Aging of U.S. Air Force Aircraft," highlighted the problems associated with maintaining an older military fleet, but age is a major safety issue for all types of aviation. It is not a problem restricted to the aircraft structure, but includes engines, avionics, and other flight systems. As a result, FAA, NASA, and DoD R&D initiatives are expanding in this area. The FAA's National Aging Aircraft Research Program is linked closely with NASA and DoD programs. A central part of research in this area is the onset of widespread fatigue damage (WFD) that could result in catastrophic failure of the aircraft. The FAA and DoD are finalizing analytical methods that will allow the quantification of the risks inherent in continuing to operate aircraft beyond their design lives. In FY99 a handbook and analysis methodology to predict the onset of WFD will be completed and validated by industry. This will greatly augment the ability of designers to build longer-lived aircraft with greater structural integrity.

As aircraft age, inspection and monitoring become increasingly important, particularly the detection of cracks characteristic of the onset of WFD. NASA and DoD are developing new tools for the inspection and non-destructive evaluation of aircraft and components, such as the corrosion detection system displayed in Figure 12. The FAA, teamed with the engine manufacturers and academia, will develop and validate industry standards for ultrasonic and eddy current inspection systems for engine components by 2003. The FAA, in concert with industry and academia, will develop inspection methods with the accuracy and resolution to detect dangerous cracks by 2004.

FIGURE 12: Probe for corrosion inspection

Propulsion Systems

Propulsion research focuses on increasing aviation safety by reducing the number of accidents that result from aircraft propulsion and fuel system failures. To accomplish this goal, researchers are addressing continued airworthiness safety issues of contemporary turbine and piston engine designs. Jointly sponsored FAA/DoD/industry workshops are held annually on the application of probabilistic design methodology to gas turbine rotating components. By 2000, the FAA plans to issue guidance, proposed Advisory Circular (ACX) 33.14, outlining probabilistic, damage tolerant design methods. New design practices also include the near-term development of cost-effective safety improvements to reduce the potential for failure in rotating engine components. In response to NTSB recommendations, the FAA and the Aerospace Industries Association are pursuing new manufacturing standards for titanium turbine engine components by 2002. Fatigue failures in engines are a particular concern for military aircraft. As a result, DoD in also investing more than $20M annually on high cycle fatigue in aircraft engines with the goal of reducing in-flight shutdowns by more than 50% by 2001. Of related interest is the development of new structures and materials to contain fragments in the event of a catastrophic component failure inside the engine. The FAA is examining the use of DoD developed advanced armor technology to help with fragment containment in commercial aircraft.

NASA's General Aviation Propulsion (GAP) program has been underway since 1988, an element of the agency's broader AGATE effort. This program aims to revitalize the American light aviation market through directed engine research, including a low-cost general aviation turbine engine. The result of this research will be highly reliable small aircraft engines that are safer, less expensive, and require less maintenance. To fuel them, the FAA is leading an effort to develop a new unleaded high-octane aviation gasoline to replace the current leaded fuels. This is being done in concert with major oil companies, and aircraft and engine manufacturers, leading to a new American Society for Testing and Materials fuel specification by 2002.

Atmospheric Hazards

Weather has long posed a threat to aviation safety. Perhaps the greatest threat stems from weather reducing a pilot's visibility. As previously mentioned, CFIT is today the leading cause of fatalities – many of these accidents were weather related. Here advanced technology is predicted to make an enormous change in the way we operate aircraft. In the future pilots will be able to "see through the weather". NASA is leading the way to make this dream a reality by bringing strategic weather information to the cockpit. When combined with new predictive tools, such as methods for estimating when clear-air turbulence will be encountered, operating crews and ground controllers will have a comprehensive map of what lies ahead. Figure 13 shows a system being pioneered at the NASA Ames Research Center to display a virtual overlay of the terrain surrounding the vicinity of an aircraft in flight. Such systems integrate GPS-based aircraft precision navigation systems with detailed topographic maps generated by high-speed computers to provide a real-time view of what lies ahead to the flight crew. This form of "synthetic vision" is just one example of the technology needed to drastically reduce CFIT accidents.

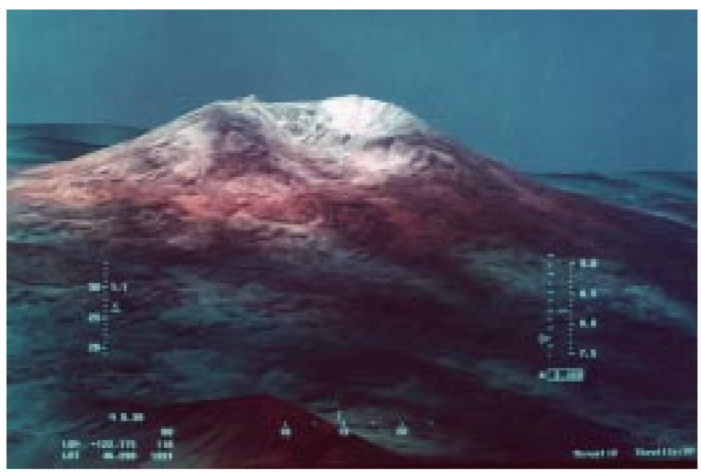


FIGURE 13: Synthetic Vision will allow pilots to maintain visual awareness despite darkness and adverse weather

In addition to obscuring a pilot's vision, atmospheric conditions can produce hazards such as lightning and icing. The FAA has undertaken a number of actions, including regulatory changes requiring air carriers to develop an approved aircraft ground deicing program, and the development of inspection methodologies and technologies to ensure that aircraft are free of frozen contamination prior to takeoff. The FAA's R&D activities include research on improving the effectiveness of deicing and anti-icing fluids. As new type of deicing and anti-icing fluids become available, the FAA, in conjunction with fluid manufacturers, Transport Canada, selected airlines, and the Society of Automotive Engineers are sponsoring tests of these fluids to establish holdover time guidelines by 2003 to estimate time-of-effectiveness of the fluids in varying meteorological conditions. Current technology deicing and anti-icing fluids employ some form of glycol which is potentially harmful to the environment. The agency hopes by 2004 to develop new fluids that significantly reduce the reliance upon glycol for aircraft deicing. Ice detection is another FAA research objective. R&D effects are being directed to prepare electro-optical and other technologies to detect the presence of frozen contamination on wide areas of aircraft by 2002. The FAA is also working closely with the NASA Lewis Research Center to better understand the aerodynamic effects associated with ice accretion on lifting services and to develop methods of predicting the potential for icing in the aircraft's flight path.

As General Aviation aircraft fly at greater altitudes icing poses an increasing threat. NASA has licensed new low-power ice removal technology to the private sector and is cooperating with commercial firms to bring active ice removal systems to small aircraft.

The FAA's research in the area of atmospheric hazards includes examining the effects of both man-made atmospheric hazards, such as high intensity radiated fields, and natural atmospheric hazards, such as lightning and stray electromagnetic radiation. Updated guidelines for aircraft lightning are expected by 2001. Research related to radiation effects are particularly important as aircraft manufacturers switch to digital flight controls and avionics systems.

Information Technology

Information technology research will help improve the accuracy of information used to plan and conduct effective aircraft maintenance. The FAA is developing a comprehensive set of risk-based decision support tools. These tools will assist Flight Standards and Aircraft Certification personnel with the daily monitoring of certificate holders (air carriers and air agencies), manufacturers, and other safety-related professionals. The FAA plans to complete the validation and implementation of risk-based decision support tools by 2003.

Accident Mitigation

Crashworthiness

The FAA is developing ways to increase protection for passengers and crew during an accident. Crash-survivable aircraft structures, cabin interiors, fuel tanks, and seat restraint systems are being developed to absorb the energy of a crash impact, thereby reducing the potential for injury. As modern aircraft increasingly employ composite structures, research is being focused on the way these materials react to impact damage. Guidelines for state-of-the-art occupant restraint systems and injury protection methodologies will be completed and released by 2003.

Researchers plan to also refine the test procedures necessary for certification standards and performance specifications based on joint FAA/NASA/DoD testing. The results of testing of the crash resistance of transport fuel tanks will be available in 1999. Expected by 2001 will be new guidance regarding the dynamic testing of transport aircraft overhead bins and fuel tanks.

Fire Safety

A fire, either in-flight, on the ground, or following a crash, immediately threatens the life of the passengers and crew. Data show that worldwide about 135 fire fatalities occurred in otherwise survivable accidents. Being able to minimize or eliminate fire-related injuries and increase survival rates for aircraft occupants during in-flight and post-crash fires is an obvious and urgent element of the R&D agenda. An FAA goal is to develop new approaches to eliminate burning cabin materials as a factor in postcrash fires. This requires new materials and the FAA is leading an effort to develop new interior substances that meet and exceed the fire resistance criteria spelled out in the Aviation Safety Research Act of 1988. Near-term goals are to develop plastic and composite materials with a 50 percent reduction in heat release rate by 2002. A longer-term objective is the development of fireproof aircraft cabin materials with zero heat release rate.

Other R&D efforts seek to improve aircraft fire detection and suppression systems, to delay or prevent the spread of fire into the passenger cabin. Near-term fire detection and suppression research is directed at developing certification criteria and minimum performance standards for cargo compartment water mist by 1999; developing an Advisory Circular for approving fire and smoke detector response rates by 2001; designing next generation fire and smoke detectors by 2002; and formulating fire safety design guidelines for oxygen systems by 2003.

Evacuation Systems

The FAA is continuing research on procedures and new equipment designs to maintain passenger safety in times of emergency and to evacuate aircraft quickly and safely in the event of a crash. By 2000 the FAA will complete research on an improved oxygen mask system. New analytical models are being prepared that simulate the evacuation of aircraft during emergencies to allow more expansive testing of new techniques. By 2003 this research will lead to a new model for evacuation in dual aisle aircraft. The FAA will continue to issue guidance resulting from evacuation research to continuously improve escape procedures for narrow and wide-bodied aircraft.

Modeling and Simulation

Data Analysis

Improving the performance of complex systems requires the integration and analysis of information from many sources. To achieve the aviation safety goals set out by WHCASS, all aspects of the aircraft and the air transportation system they operate within must be studied in detail. The FAA and NASA have initiated R&D activities to capture, correlate, and analyze a far greater amount of information related to the performance of the airspace system than ever before.

In conjunction with the FAA, NASA, in 1976, created the Aviation Safety Reporting System (ASRS) to capture voluntarily submitted aviation safety reports from pilots, air traffic controllers, and others in the aviation community for use in analysis and research. This information is used to inform both researchers and operators of airspace system trends. Additionally, the FAA has created the Global Analysis and Information Network (GAIN) to serve as the focal point for all information related to aviation safety matters. When combined with airline Air Safety Reports, air traffic control radar tapes, digital flight data, and the National Transportation and Safety Board's (NTSB) accident data base, a powerful new information architecture is taking shape that will help illuminate the path for R&D programs.

The information revolution is heavily impacting the aviation community. Flight data recorders on many of today's large airliners measure only a few operational parameters. Those on the latest Boeing 777 record 700 flight parameters 8 times a second. Information on normal and safe flights is also being retained, aiding the ability of researchers to develop highly accurate baselines from which to measure deviations. An accurate knowledge of normal operations improves the chances of detecting anomalies early.

Patterns of deviation that could lead to unsafe conditions often lie undetected in operating environments that otherwise appear normal. Advanced "intelligent agent" software will hunt for these hidden patterns and new techniques for "mining" data will transform operational data into forms more useful for researchers and technologists.

Sharing of Safety Information

The FAA, NASA, DoD, in coordination with the NTSB, have created an ability to share information that exploits the capabilities of high-speed networks. The sharing of information must be sensitive to issues of information ownership and the need to safeguard proprietary data. The success of information sharing efforts, particularly the strong relationship with commercial manufacturers and operators, indicates the strength of the techniques being applied and the degree of partnership that has been created. More advanced forms of data sharing seek to move information more quickly and more broadly, bringing the global aviation community into alignment with aviation safety goals being pursued in the U.S.

Monitoring

ASRS is an important step in the improved monitoring of the airspace system from a safety perspective. NASA has developed other tools with which to sense the overall health of the America's aviation infrastructure.

Achieving unprecedented levels of safety requires monitoring the actual daily performance of the airspace system. All airline companies closely observe daily fleet operations and the larger carriers routinely collect and analyze a vast amount of information. NASA is creating the Aviation Performance Measuring System (APMS) to assist airline companies harvest this information for insights related to safety. With APMS, NASA is building the tools that allow operators to visualize the performance of their systems in novel ways. The process of using actual flight information to detect anomalous operations is known as Flight Operational Quality Assurance (FOQA). FOQA programs have been in use by European carriers for over two decades. Today over 30 U.S. carriers are using FOQA programs to monitor adherence to prescribed operational guidelines. NASA's APMS will enable airline companies to take the next step -- to more fully identify potential hazards to safety as they examine FOQA data. The monitoring of operations using APMS will be, therefore, a near-real-time test of the effectiveness of evolving safety procedures and technologies. The information that airlines gather in regard to operations is highly proprietary. The government must act to protect this privacy in recognition of the broader goal of reducing accident rates.

Monitoring programs like APMS will produce three outputs: the elaboration of new baselines for system-wide safety and performance; in-depth analysis of emerging trends; and the measurement and communication of risk. The goal is to develop a new generation of system-wide monitoring networks that continuously take the pulse of the operating air transportation system. By 1999, NASA plans to test aviation system safety monitoring networks and use them to develop management aids for improved overall performance.

Modeling

Greatly expanding the quantity and quality of information used to characterize the airspace system and speeding access to that information provides the foundation for building better predictive performance models. Safety concerns, whether they are existent or emergent, can be tested with higher fidelity using these data. At the nexus of improved data analysis and broader monitoring lies NASA's Methods for Analysis of Systems Stability and Safety (MASSS) program. The MASSS program seeks to model the total aviation system, from the perspective of what is happening today and how new technology will impact it in the future. MASSS brings advanced simulation tools to the evaluation and prediction of the health and status of the integrated airspace system.

A Safer, More Efficient Air Traffic Network - Implementing Goal 2

Sidebar: The NAS Modernization Plan

Tomorrow's skies must be safer, but air transportation must remain efficient and affordable. American airline companies and manufacturers must also continue to be world leaders and be able to operate with assured economic viability. Developing a National Airspace System (NAS) for the next millennium requires careful and cooperative planning. The FAA has announced plans for a new NAS architecture (see sidebar) that will accomplish these objectives while also minimizing disruption and maintaining safety during the transition. Imbedded in the new architecture is the promising development of "free flight" – the direct flight of aircraft using Global Positioning Satellite (GPS) precision navigation.

To meet the expected 50% increase in domestic air travel, the WHCASS recommended that the upgraded NAS be ready by 2005. The new NAS architecture incorporating free flight is a dramatic change in existing operational techniques and it places heavy demands on aviation R&D organizations. There are many challenges. Financing this upgrade in a constrained budgetary environment is especially challenging. General aviation aircraft, an important component of the flying community, must have available affordable avionics in order to safely operate in this new domain. Another factor is the critical importance of our national space assets. The accuracy, reliability, and availability of precise navigational signals must be assured. Of particular concern is protection of the radio frequency spectrum in which navigation signals are transmitted. These frequencies must remain clear of interference and intentional or inadvertent blockage from domestic or foreign transmitters.

As the FAA leads the way towards the modernized NAS architecture it will rely heavily on R&D efforts within both DoD and NASA. The DoD is the largest operator of aircraft in the world. The combined military services operate a total of 16,300 aircraft. As an air traffic control provider, DoD facilities handled 11% of all air traffic nationally in 1995. This amounted to 18.4 million aircraft of which 3.7 million were civilian and 14.7 million were military. Also, the GPS system is operated and managed by the U.S. Air Force that maintains an on-going research program to improve the performance and reliability of the system. The DoD is conducting extensive research into ATC improvements and the integration of military aviation into the NAS architecture.

NASA has set a goal to *triple the aviation system throughput, in all weather conditions, within IO years* while maintaining safety. The Aviation Capacity Research (ACR) initiative is the agency's principal means of assisting the FAA's NAS modernization effort. The ACR initiative crosses all vehicle classes: conventional air carrier, vertical-take-off and landing (VTOL) and rotorcraft, commuter and short-haul aircraft, and military. NASA's AATT program is an ACR element established to enable substantial increases in the efficiency and capacity of aircraft operations within both the national and global air transportation system. The Terminal Area Productivity (TAP) program of the ACR initiative is designed to increase airport terminal area capacity in non-visual, or instrument-weather conditions. TAP constitutes NASA's commitment to alleviating airport area congestion. Additionally NASA's Advanced Subsonic Technology (AST) program sponsors extensive research into general aviation and how small aircraft will operate in the new NAS architecture.

Federal programs to improve the air traffic network fall into the two areas shown in Figure 14. Each of these areas represents several disciplines critical to the success of the overall effort. As shown in Figure 15, this investment of nearly $1.3 billion will be invested on R&D related to the development of a safer, more-efficient air traffic system. Each will be described below with highlights of the research objectives of each of the principal R&D performers.

Figure 14: Investment areas for air traffic improvement

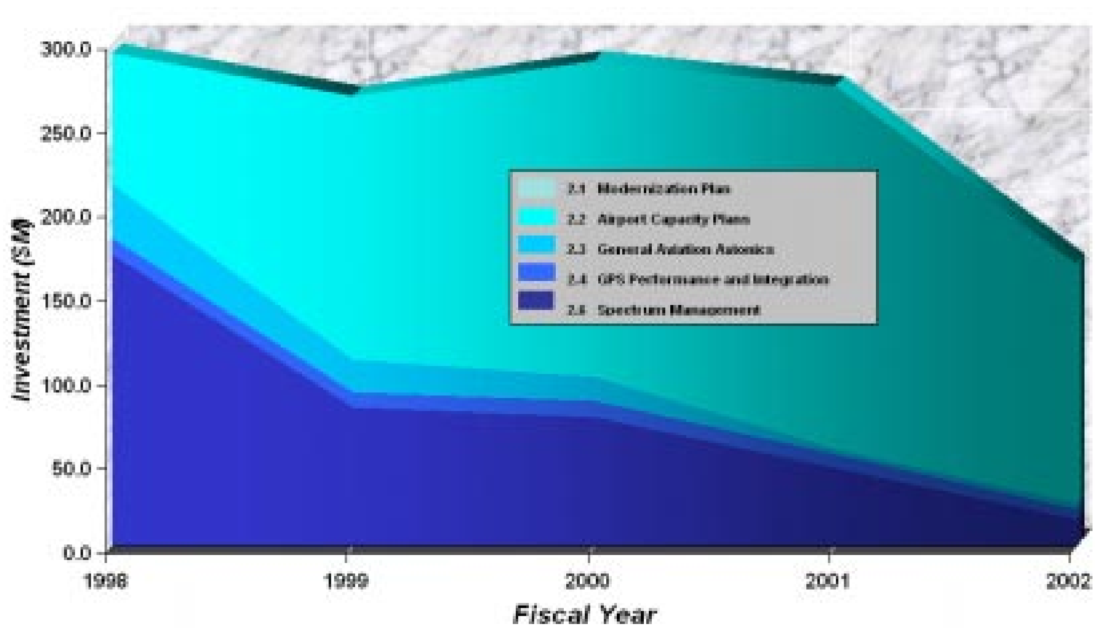


FIGURE 15: R&D related to the development of an air traffic management system of tomorrow represents and investment of more than $X billion over the next 5 years.

Air Traffic Management

The movement of aircraft en route is today managed by an extensive ATC system that already experiences constraints. Research in managing air traffic must set goals to improve system safety, reduce delays, improve access to airports during inclement weather, increase reliability, and improve productivity.

Free Flight Implementation

Free flight is a new method of air traffic management that depends on successful cooperation among all members of the aviation community. Both the WHCASS and the Radio Technical Commission for Aeronautics (RTCA) Free Flight Steering Committee have called for a detailed operational concept to guide the implementation of free flight. A joint concept of operations (Joint CONOPS) for free flight has been developed by the FAA, DoD, and the aerospace industry. It outlines a transition from the point-to-point operations of today to an initial deployment of free flight through 2000, a scale-up to 2005, and mature free flight operations in the post-2005 timeframe.

The Joint CONOPS will be validated in two ways. In the near-term, the FAA's Flight 2000 program will test key aspects of free flight and the modernized NAS architecture by implementing new procedures and technology in the regions of Hawaii and Alaska. Flight 2000 is an aggressive initiative with oversight from the Flight 2000 Steering Group consisting of members from the FAA, NASA, and the U.S. aviation industry. This will be a full-scale operational demonstration and validation of the concepts proposed for the NAS modernized architecture. Flight 2000 will involve all classes of users in all phase of flight operations and surface movements. The aircraft involved will be carrying next generation communication, navigation, and surveillance (CNS) systems being designed to offer affordable avionics for the future of air travel.

Flight 2000 will be a crucial milestone on the road to safer, more efficient, and more economic air travel.

High Capacity Planning

The FAA is also developing traffic models and working with the staff of major airport to redesign traffic patterns and operational procedures. So far more than 50 major airport studies have been conducted and improvements are calculated to save between $75 and $100 million per airport annually. Similar studies have been completed, and more are underway, of high traffic corridors, such as the Chicago, Atlanta, and Jacksonville regions.

The most dominant factor in the ability of the NAS to maintain capacity is the ability of the weather to constrain operations at major airports. Weather minimums, imposed to assure the safety of the traveling public, are being reexamined to see if new technology can safely reduce the operational thresholds thereby reducing the impact of adverse weather on flight operations. Additionally, the FAA is working closely with the National Weather Service and the National Oceanic and Atmospheric Administration to develop advanced aircraft sensors to help forecast in-flight conditions. Studies of weather effects, storm decay, and turbulence prediction are also expected to greatly improve our ability to accurately predict the onset of adverse conditions and plan accordingly.

Oceanic Flight

Oceanic air travel is expected to grow by more than 30% over the next 5 years. To handle this expansion the FAA is developing the Advanced Oceanic Automation System (AOAS). The goal of AOAS is to move oceanic flight closer to the concept of free flight. To accomplish this U.S. and oversees controller, as well as en route aircraft, must be able to share information and select flight profiles that accommodate higher traffic densities. With AOAS in place, pilots will be able to fly more fuel-efficient routes, taking advantage of winds aloft, and using more efficient weather-avoidance procedures.

Advanced Communications, Navigation, and Surveillance (CNS)

In the modernized NAS architecture, communications will be digital and more information will be relayed, precision navigation will improve all-weather operations, and new surveillance systems will help prevent conflicts in terminal, en route and oceanic airspace. CNS technologies are heavily dependent on satellites requiring the integration of air and space assets.

In the future, better cockpit communications will advance the concept of a more self-reliant pilot, reducing air traffic controller workload and voice traffic congestion. Digital aircraft communication systems will in large part be based on research conducted by the DoD, most notably the U.S. Air Force and the Defense Advanced Research and Projects Agency (DARPA). The FAA is working closely with DoD in the development of digital communication systems that are software reconfigurable. Validation of these systems is expected by 2003. The digital transmission of voice and data to aircraft will also increasingly rely on satellite communications. The FAA and NASA are working closely on functional specifications for satellite-based data links to move large volumes of information to the cockpit.

Satellite-based precision navigation is having a profound effect on aircraft navigation. The FAA will approve Category I precision approaches using GPS-based technologies by 2001. Category II/III precision approaches will follow with the deployment of local area augmentations to satellite-based navigation signals. Prototype local area augmentation technologies will be demonstrated by 2003.

Coincident with the development of advanced communications systems and precision navigation technologies is the need to locate all aircraft within a given location in order to ensure that flight path conflicts do not occur. This is the foundation upon which the concept of free flight is based. The FAA, NASA, and DoD are cooperating on the development of Automatic Dependent Surveillance systems with a broadcast capability (ADS-B). ADS-B systems will derive aircraft position using GPS-based technology. Aircraft identity, altitude, and position information will be integrated and digitally broadcast to ground receivers and nearby aircraft. When received by an aircraft, these signals will be processed and displayed to the pilot. Specifications for ADS-B systems are to be completed by 2003.

General Aviation Programs

General aviation (GA) is a diverse and vital part of our nation's future. It consists not only of private pilots, but also business aircraft operators, owners of historic aircraft, and airborne emergency medical services organizations. GA is not limited to small piston-engine aircraft – it includes experimental machines, high-speed jet aircraft, and rotorcraft, including tiltrotors.

Safety is the primary concern for the future of GA. More than 90% of the accidents tracked by the NTSB are attributed to GA, and nearly half of the recorded accidents were related to failures of the flight crew. Flight crew training is therefore a major focus of the FAA's GA program. Another important factor is that GA flying is often uncontrolled. In general, GA aircraft cannot benefit from the extensive radar services currently available due to high equipment costs. The advent of GPS, in addition to the development of lower cost, high reliability electronics, promises to make navigation services more broadly available to the GA community. The FAA, NASA, and avionics manufacturers are cooperatively exploring revolutionary new low-cost systems that will automatically alert pilots of traffic conditions and cockpit displays that display the flight of other aircraft. The FAA expects to issue new standards for low-cost avionics in 2001.

Rotorcraft are a particularly important element of future aviation. Helicopters are often involved in rescue operations that require flight during bad weather and poor visibility. Vertical flight also requires approaches that allow the rotorcraft to decelerate prior to landing. Precision approach procedures and criteria developed for winged aircraft are often inappropriate for rotorcraft. The FAA is developing new procedures for vertical flight that will allow instrument approaches into heliports and GA airports using GPS-bases systems. Prototypes of avionics to support this need are projected to be available in 2001.

Advanced CNS technology will profoundly change the face of aviation. As new CNS technologies are being introduced to the market they are mainly focused on the commercial airline industry. NASA is working to ensure that CNS advances are also responsive to the needs of the GA community, as they must for the modernized NAS architecture to succeed.

Airport and Terminal Operations

The FAA reports that 23 of the nation's busiest airports are currently experiencing more than 20,000 hours of delays each year. Delays costs airline operators an estimated $3 billion annually and the congestion bespeaks of potential safety hazards. Delays and congestion are often related to inclement weather. As air traffic increases, the ability to schedule arrivals and departures for the smoothest possible flow becomes increasingly important. The FAA and NASA are working closely on improving air operations in the airport vicinity. As a leading operator of aircraft the DoD is providing a broad experience base of high-density air operations and making important technical contributions to the effort.

Runway Incursion Avoidance

The FAA is leading an effort to eliminate runway incursions as a source of accidents. Teamed with NASA, research in underway to develop surface radars to track aircraft and issue alerts when conflicts arise. Several radar systems are currently being evaluated and selection of the appropriate architecture is expected by 2003. Such systems are especially important for avoiding conflicts in low visibility conditions. An example of this technology is NASA's Dynamic Runway Occupancy Measurement (DROM) system. DROM works in conjunction with other computer-based systems to determine the spacing of landing aircraft, and ensure that runways are clear of conflicting traffic. DROM does this by predicting the time it takes for a given type of aircraft to land and clear a runway and passing this information to other flight planning systems. The DROM system has been field tested at the Hartsfield-Atlanta International Airport.

High Capacity Operations

NASA is assisting controllers manage a much higher density of air traffic while maintaining safety margins through an integrated set of advisory tools. The Traffic Management Advisor (TMA) assists air traffic controllers by increasing awareness using advanced graphical displays and alerts. The system generates statistics and reports about the traffic flow and estimates the time of arrival for each aircraft entering controlled airspace. TMA also recommends a runway assignment to optimize the traffic flow. A Descent Advisor (DA) provides advisories that ensure fuel-efficient and conflict-free descents with highly accurate arrival times--on the order of 10-20 seconds. NASA's Passive Final Approach Spacing Tool (P-FAST) is another decision support tool for air traffic controllers. Terminal air traffic control usually commences about 40 nautical miles from a major airport. Using P-FAST controllers manage landing sequences and runway assignments to properly space the flow of traffic on final approach. Advisory systems are being field tested in operational environments (see Figure 16).

FIGURE 16: Advanced advisory tools under test at Denver's Stapleton Airport.

Other NASA developments aim to reduce the current separation requirements for landing aircraft in order to increase throughput. The Aircraft Vortex Spacing System (AVOSS) provides precise separation to avoid a landing aircraft from touching down before the wingtip vortices from the preceding aircraft have safely dissipated. The system uses sensors to measure the passing of an aircraft's vortex and adjusts the separation requirements appropriately. The Airborne Information for Lateral Spacing (AILS) system monitors the distance between aircraft approaching parallel runways using ground-based differential GPS devices. AILS will allow aircraft to safely operate in closer proximity as the approach parallel runways.

Ground Traffic Flow

Reducing the separation of aircraft in a landing pattern is important to increasing throughput. Yet if corollary improvements are not made in the flow of aircraft after landing, congestion is likely to occur on taxiways and ramp areas. NASA is pioneering a system called Taxi Navigation and Situational Awareness (T-NASA) which could significantly improve the ability to move aircraft swiftly to and from terminal gates. T-NASA will rely on computer displays to relay taxi instructions to the pilot and provide a moving image of the aircraft and other traffic in the proximity. Such a system will allow higher taxi speeds, even at night and during periods of low visibility. A related development is a system called Roll Out and Turn Off (ROTO). ROTO displays information to the pilot to optimize braking distance. This will help to minimize the aircraft's occupancy time on the runway.

Ground controllers must also be able to monitor the location and movement of aircraft moving to and from gates. The FAA and NASA are jointly developing a Surface Movement Advisor (SMA) to assist with the coordination and planning of ground airport traffic operations. The SMA concept integrates airline schedules, gate information, flight plans, radar data, and runway configurations to help ground controllers optimize the movement or arriving and departing aircraft.

Security for the Air Traveler - Implementing Goal 3

Sidebar: High-Tech Sniffing – Advanced Bomb Detection

Ensuring the security of travelers is a primary goal of the Administration's current and future vision of the air transportation system. The threat of terrorist disruption is real and it has a changing face. The U.S. no longer faces just an overseas threat -- citizens and property are being threatened domestically, in some cases by misguided fellow Americans. Additionally, terrorists are increasingly found working alone or in small groups, stepping beyond the established groups well-known to Federal security agencies.

It is imperative that advanced technology be employed to meet a potentially more aggressive and sophisticated adversaries. The central goal of the Federal investment in aviation security is to broaden the research, development, and implementation efforts in order to field the most effective security technologies possible. Promoting the security of the travelers will inspire public confidence and help assure the economic success of a critically important industry.

In contrast to the other R&D areas covered in this report, aviation security requires less Federal investment. Although there are many ambitious R&D projects underway related to security, most of the effective steps that must be taken to combat terrorism represent changes in rules, regulations, policies, and operating procedures. Also, many R&D efforts in this area are moving into implementation having matured new technologies that are proving highly effective deterrents.

The WHCASS recommended that the FAA should lead Federal efforts related to aviation security R&D. NASA had little or no specific responsibility in this research area. The DoD actively supports FAA initiatives, working to bring military technology and experience to combating emerging threats. The FAA is also working closely with many legislative and executive branches, including US Customs, US Postal Department, the FBI, the CIA, and various defense agencies.

The Aviation Security Improvement Act of 1990 recognized that "the safety and security of passengers of United States air carriers against terrorist threats should be given the highest priority." Since it's passage the FAA has conducted extensive reviews of airport security and improved the posture of security in and around airports across the country. The FAA continues to lead efforts to improve civil aviation security through strategic investments in high technology and more advanced procedures. Terrorists too can use new technology, so the FAA and it's R&D partners must continually develop new solutions that are proven to effectively deter and mitigate the effects of incursions. Technological solutions must be comprehensive, addressing security vulnerabilities at airports, air traffic control facilities, and aircraft. Also important is protecting the security of supporting elements in the air transportation infrastructure – the information systems through which critical data moves and the navigation satellite network upon which air travel increasingly relies.

The level of investment of Federally sponsored aviation security R&D is shown in Figure 17. Over the next five years nearly $600 million will be invested in related research. DoD participation in this effort is particularly important. Research into new counterterrorism tactics and equipment are heavily based within DoD offices and efforts to improve the security and integrity of the GPS navigation network are the responsibility of the U.S. Air Force. FAA and DoD cooperation in this area is particularly strong, as are alliances with industry, academia, and foreign governments. It is important to note that investments by the FAA related to aviation security are heavily leveraged. For example, a partnership with the Defense Advanced Research Projects Agency (DARPA), in which FAA investments were $25,000, resulted in airport security research efforts exceeding $16 million. One recent industrial partnership resulted in a materials detection program worth $35 million from a $5 million FAA investment. The FAA is also cost-sharing with industry to accelerate the development and certification of advanced explosives detection systems (EDS).

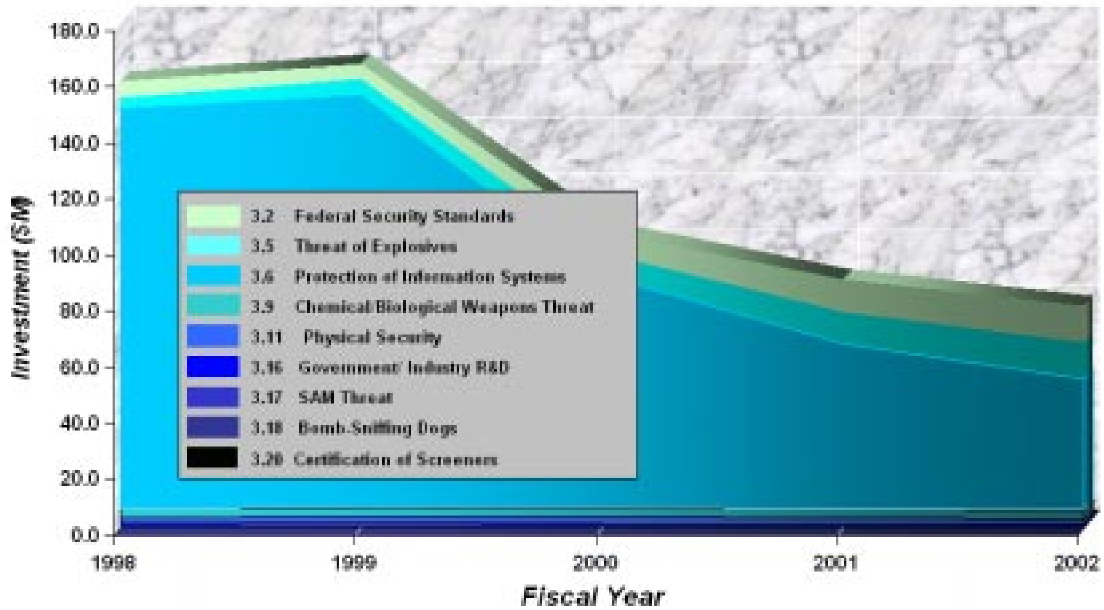


FIGURE 17: The Federal government will invest over $600 million on a broad spectrum of research projects.

As seen in Figure 18, the Federal aviation security R&D investment falls into six categories: explosive and weapons detection, improved airport security, human factors, aircraft hardening, counterterrorism, and satellite network protection. Each of these investment areas contributes importantly to the overall goal of protecting air travelers. They are described below.

Explosives and Weapons Detection

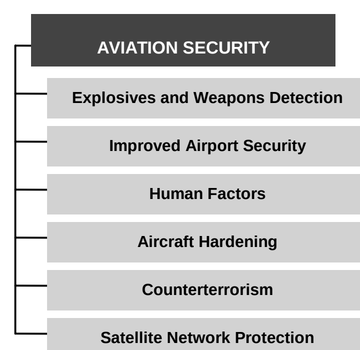


FIGURE 18: Federal R&D investments are comprehensive and results-oriented.

On December 21st, 1988 the world was shaken by the bombing of Pan Am Flight 103 over Lockerbie, Scotland, a dastardly act that killed 270 people. The Lockerbie incident focused attention on the importance of explosives detection and led to accelerated efforts to develop solutions to prevent future occurrences. Federal R&D related to explosives and weapons detection seeks to develop new and improved methods and technologies to identify explosives in checked and carry-on baggage, on passengers, in air cargo, and in mail, primarily prior to aircraft boarding. Further, the goal is to eliminate the possibility of a terrorist successfully concealing explosive devices, weapons, and flammable gas or liquid explosives on aircraft.

There are several strategies for meeting this goal. Bomb-sniffing dogs, for example, have proven a very effective means of detecting explosive materials, and improved inspection procedures can help identify and expose terrorist agents. Eliminating the potential of using explosives and weapons in the air transportation system, however, relies on making improved EDS technology available to the airlines and groups responsible for airline security (domestic and international). New systems must prevent terrorist exploitation of explosives and weapons while supporting higher passenger flows. They must also be cost-effective and support the objectives of the air transport industry to provide secure and affordable travel.

The FAA leads the world in research related to detecting explosives and weapons, with oversight provided by the National Academy of Science which review R&D priorities. Close cooperation with other government agencies and industry is critical to the success of the FAA initiatives related to detection technologies. For example, the FAA worked with InVision Inc. to develop the world's first certified EDS in the world (see Figure 19). Current research is focusing on developing miniature systems that are portable in the airport environment, reducing false alarm rates, and speeding the integration of EDS-type technologies into related systems. New techniques of detecting explosives and weapons are currently being examined (see sidebar). Techniques for tracing emerging threats, such as biological or chemical agents, are also being developed. New systems will be more fully automated and be capable of thoroughly screening carry-on equipment.

FIGURE 19: EDS technology is now being sold domestically and internationally.

Airport Security

Preventing unauthorized access to aircraft and airport facilities in another important aspect of aviation security. R&D development in this area focuses on equipment to monitor and control perimeters, automated access systems, and passenger baggage matching systems to prevent unaccompanied luggage from being loaded into aircraft.

Unaccompanied passenger baggage is a particular problem related to aviation safety. Positive passenger baggage matching (PPBM) systems, which track items of baggage using radio frequency transmitters, promise to dramatically improve the ability of security personnel to monitor the flow of material through the airport. The cost of PPBM systems is an important consideration in their deployment.

New security technologies must fit into existing and planned infrastructure. The FAA's Airport Security Technology Integration (ASTI) program provides information and interacts with domestic and international participants to ensure the smooth adaptation of new systems. For example, the ASTI program in 1999 will finalize a standard for communication between advanced detection systems and automated baggage-handling systems. Such a standard is critical to effective use of the new detection technologies. Additionally, the ASTI program will finalize a passenger baggage flow model. This model will be used by airport and airline planners when designing security installations in existing and future terminals. The ASTI program is being implemented in close cooperation with the Air Transport Association (ATA) and the Regional Air Carrier Association (RACA) to study how best to implement these new technologies.

Designing solutions hinges on being able to predict future threats that the aviation community may face in the near future. Threat assessments rely on close cooperation between the FAA and DoD. The U.S. Air Force and the Defense Special Weapons Agency are also teamed with the FAA to simulate and model blast effects and biological and chemical effects on aviation facilities. The FAA also works closely with the DOD Office of Special Technology to coordinate activities relative to technology assessments.

Human Factors

Improving the performance and effectiveness of people engaged in the security profession is also reinforced through long-term R&D. New techniques for selecting and training personnel, implementing designs that can be readily operated, and protecting the health and safety of employees and travelers are all aspects of this research. Increased use of automation will also help reduce security costs and reduce the vulnerability of security systems to terrorist threats.

The FAA is developing the Screener Proficiency Evaluation and Reporting System (SPEARS) to improve the definition of the knowledge and skills needed for checkpoint screening. SPEARS will also provide data needed by researchers in developing new detection systems. Additionally, new techniques for profiling passengers are being devised by the FAA. Profiling assists security personnel by focusing attention on high threat individuals in the airport environment. By streamlining profiling methods, security personnel can reduce the number of passengers needing special security treatment. Optimized human performance contributes to the overall performance of aviation security system. The FAA's Human Systems Integration program aims to merge individual detection systems into a more cohesive structure with similar interfaces to improve operator accuracy and throughput.

Aircraft Hardening

The focus of Federal aviation security programs is prevention; creating an infrastructure that precludes terrorist intervention. No system is foolproof, however, and other steps must be taken to ensure that the air transportation system is robust. The purpose of the aircraft hardening effort is fourfold:

- Increase the survivability of aircraft if an explosion aboard should occur.
- Accurately estimate the amount of explosive needed to cause aircraft damage – this information informs explosive detection programs.
- Protect aircraft avionics and sensitive systems for the damaging effects of electromagnetic or high-energy interference.
- Assess and mitigate the threat to commercial aircraft from surface-to-air missiles and to investigate effective countermeasures to this threat.

The FAA and DoD are working closely to study the damage characteristics of explosive charges of various type, size, and location. DoD's Transport Aircraft Survivability Program has helped refined standards for the design of explosion resistant luggage containers that the FAA is now working with industry to implement. The result will be cost-effective, lightweight designs that can be readily integrated with existing ground-handling equipment. This effort includes cooperative planning and development with government and industry representatives from the United Kingdom and France. Transfer of explosion-resistant container technology is expected by 1999.

Terrorists are using advanced technology to achieve their objectives and one of the greatest threats is posed by surface-to-air missiles. The proliferation of man-portable air defense systems (MANPADS) has led security analysts to warn that they pose a major threat to airline safety. Programs are underway to assess the threat of MANPADS, as well as electromagnetic and projected energy systems, on the safety and security of commercial aircraft. The goal of this effort is to fully examine the vulnerabilities in the current and planned air transportation architecture and to devise effective countermeasures to terrorist intervention.

It is likely that DoD efforts to improve aircraft survivability will spillover to the private sector. Both the military and commercial aircraft industries share an interest in low-cost, lightweight solutions to meeting survivability requirements. The DoD, FAA, and industry are working to ensure the transfer of technology as rapidly as possible.

Counter-Terrorism

Checking terrorist attacks against the air transportation system is of paramount importance if security goals are to be met. DoD is making counterterrorism technology available to civil agencies as quickly as possible, such as advanced surveillance systems to detect intruders in airport environments. The FAA is working closely with the International Civil Aviation Organization (ICAO) to build the bridges necessary to strengthen international standards for heightened security measures at airports. These standards must be uniform and strict, and implemented as rapidly as possible.

Considerable research is also being conducted to explain the factors underlying state-sponsored terrorism. Both empirical and theoretical models are being developed to monitor worldwide trends in the repression that spawns terrorist acts. These models will help profile the emergence of terrorism, supporting the coherent development of systems and processes designed to effectively neutralize future threats.

Satellite Network Protection

Protecting the health and security of navigation signals is of fundamental importance, both for U.S. national security and the preserving the safety and integrity of all modes of transportation. As the nation and the world transition to free-flight, air transportation will shift from ground-based radio navigation to a strict dependency on satellite-based navigation. The growing interdependency of airborne and space assets was highlighted in the recent Presidential Decision Directive 63 (PPD-63) that specifically notes the importance of protecting the security of space-based assets.[4] The U.S. Global Positioning Satellite (GPS) system will be the backbone of America's navigational network. FAA augmentations to the GPS infrastructure, the Wide-Area Augmentation System (WAAS) as well as local augmentations, build upon the basic GPS architecture.

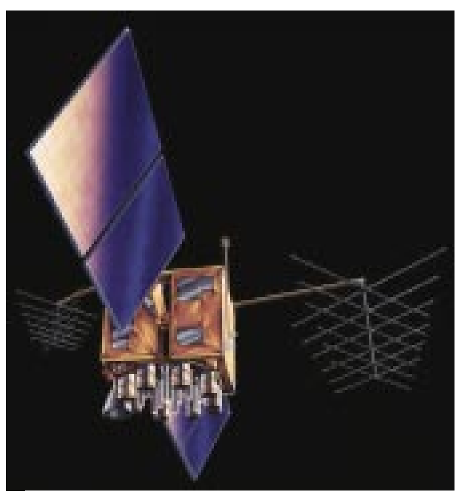


FIGURE X: GPS Block 2R satellites are now being deployed.

GPS was designed to meet the needs of U.S. forces operating within military theaters. GPS will continue to respond to military requirements while also serving the expanding needs of the global transportation community. The President's 1996 U.S. GPS Policy stipulates that DoD acquire, operate, and maintain the 24 GPS satellite constellation (see FIGURE 20). In addition, DoD maintains the Standard Positioning Service which is the civil and commercial service provided within the GPS design. The challenge for DoD is denying the use of GPS signals to adversaries during times of conflict while maintaining uninterrupted service to friendly forces and civil and commercial users outside of the military theater of operations. DoD researchers and planners are conducting extensive research to preclude jamming of GPS signals or other purposeful acts of interference. Advanced receivers and antenna electronics will ensure signal integrity and protect military forces operating in the field

[4] The President's Commission of Critical Infrastructure Protection's Report ***Critical Foundations*** provided the key recommendations that led to Presidential Decision Directive 63, and the related PDD-62 on combating terrorism. The report is available in electronic form at http://www.pccip.gov/.

Another important issue related to GPS operations is preserving the radio spectrum in which the satellites transmit their signals. Because GPS signal are transmitted at low power, the GPS spectrum must remain exceptionally clear of interfering noise. The increasing threat of incursion into GPS operating frequencies is being met with the strongest response by the U.S. government. Research continues on ways to strengthen control and transmission signals and provide additional guards against interference.

Summary

President Clinton’s goal of reducing the fatal aircraft accident rate by 80% within 3 years is an ambitious goal. It is additionally a very important goal for the traveling public and for the economic health of America’s aviation industry. American citizens will increasingly rely on the air transportation system to meet their business and pleasure travel needs. It is imperative that the safety and security of the traveling public not be placed in jeopardy and traffic loads increase, nor must terrorists be permitted to hold hostage a vital national resource. There are many regulatory and operational changes that go hand-in-hand with improving aviation safety and security, but none are more important than ensuring a vital, well-integrated R&D program. The President has set forth an R&D agenda aimed at accelerating and focusing Federal initiatives related to aviation safety and security to ensure that solutions are ready when needed.

The FAA, NASA, and DoD are pledged to work cooperatively with industry, academia, and the world community to see to it that the recommendations of the White House Commission on Aviation Safety and Security are met as expeditiously as possible. The FAA is taking the lead in the planning and execution of these efforts in order to make sure that the results of R&D projects are smoothly integrated into planned changes in the air transportation system. The R&D portfolio is comprehensive and balanced. The needs of airline operators, general aviation pilots, and airport administrators have influenced and will continue to influence the objectives of Federal research in this area. Federal agencies will also remain committed to a partnership with industry, both to ensure that solutions are cost-effective and to provide opportunities for American firms to bring to market new designs that are inherently safe and secure in terms of terrorist intervention.

Behind all sound plans is a vision. The Administration envisions a future in which airline passengers travel with assured safety and security, but also with increased efficiency and comfort. The R&D being conducted today and in the near future will make this vision a reality as we enter the next millennium.

SIDEBAR 1: Windshear Avoidance – a Success Story

Windshear is a generic term referring to any rapidly changing wind currents. A type of weather phenomenon called "microbursts" can produce extremely strong vertical winds, posing great danger to aircraft. These are local, short-lived downdrafts that radiate outward as they rush toward the ground. As a downdraft spreads down and outward from a cloud, it creates an increasing headwind over the wings of an oncoming aircraft. This headwind causes a sudden leap in airspeed, and the plane lifts. If the pilots are unaware that this speed increase is caused by windshear, they are likely to react by reducing engine power. However, as the plane passes through the shear, the wind quickly becomes a downdraft and then a tailwind. This reduces the speed of air over the wings, and the extra lift and speed vanish. Because the plane is now flying on reduced power, it is vulnerable to sudden loss of airspeed and altitude. The pilots may be able to escape the microburst by adding power to the engines. But if the shear is strong enough, they may not be able to recover. Pilots need 10 to 40 seconds of warning to avoid windshear. Fewer than 10 seconds is not enough time to react, while more than 40 is too long -- atmospheric conditions can change in that time.

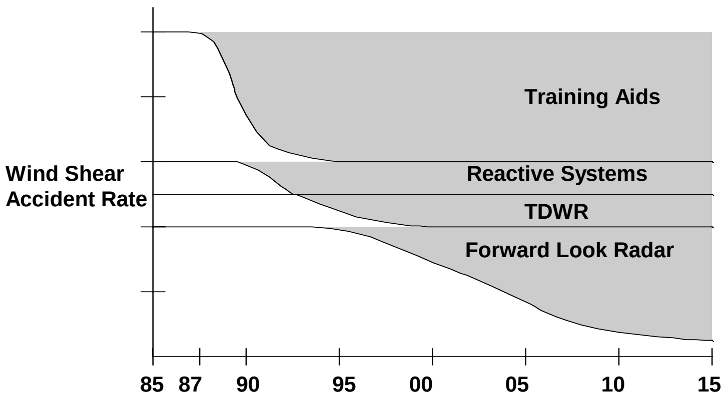


FIGURE 21: Reducing windshear incidents required change across the board and involved all parties.

As shown in Figure 21, the initial response to windshear accidents was extensive ***training*** programs for pilots and air traffic controllers. This effort depended upon heavy investments made by the airline operators in conjunction with the FAA and the NTSB.

Improvements in training procedures made a significant contribution to reducing the windshear accident rate, but equipment manufacturers have used available technologies to further reduce the number of windshear incidents. These are ***reactive systems*** that warn pilots when windshear conditions are in effect. The Level Wind-Shear Alert System, for example, has been installed on the ground at more than 100 U.S. airports. Wind speed and directional sensors report to a central computer, and controllers can alert pilots in the event a windshear is detected.

Reactive systems are limited in that they cannot predict when windshears are approaching. A longer-term development effort was initiated by government and industry to develop ground-based ***Terminal Doppler Weather Radar*** (TDWR) systems. TDWR was tested at Orlando, Florida, and Denver's Stapleton airports and by mid-1994 were stationed at more than 40 other airports across the nation. Though these systems help predict windshear events they do not represent the ultimate solution. Even with TDWR systems installed airborne detection is still needed because windshear is a global phenomenon and most airports will not have predictive systems installed.

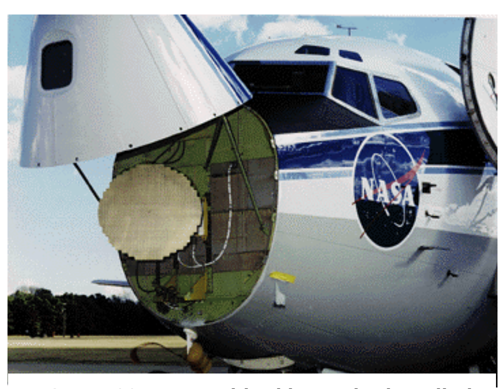


FIGURE 22: Forward-looking radar installed in NASA research aircraft.

Systems that allow the pilot to predict what lies ahead using aircraft based sensors required a long-term R&D effort and heavy Federal investment. ***Forward-looking radars*** (see Figure 22) were developed to send a signal ahead of the aircraft to seek raindrops and other moisture particles. The returning signal represents the motion of those raindrops and moisture particles, and this is translated into wind speed. Doppler

LIDAR (light detecting and ranging) is another technique that reflects energy from "aerosols" (minute particles) instead of raindrops. This system can avoid picking up ground clutter (moving cars, etc.) and thus has fewer interfering signals. Another alternative technology is infrared detectors to measure temperature changes ahead of the airplane. The system monitors the thermal signatures of carbon dioxide to look for cool columns of air, which can be a characteristic of microbursts.

Since 1986, the FAA, NASA, and DoD have work closely to develop methods of detecting and avoiding hazardous windshear. The result is a continuing effort to eliminate windshear as a cause of fatal accidents – an effort that has a dramatic impact on the safety of the traveling public.

SIDEBAR 2: NAS and "Free Flight"

To address the challenge of modernizing the NAS, the FAA has embarked on an effort to modernize the air traffic control system in a realistic, economically-feasible manner with minimal disruption to users. As part of that effort, the FAA released in October 1996 a version of its new NAS Architecture, a comprehensive system blueprint for the aviation infrastructure for the next 20 years. The NAS architecture serves as a comprehensive plan to modernize the control infrastructure in a way that benefits both users and service providers.

After issuing the draft plan, the FAA began a major outreach effort to involve the aviation community in NAS architecture development. The agency distributed nearly 3,000 copies of the architecture and received more than 2,500 comments from industry, government, academia, and system users. The FAA used these comments to address the concerns of the aviation community and it began to adjust the modernization plan and develop a refined baseline. The latest NAS architecture lays out a master plan that will support greater user flexibility in planning and conducting flights with increased safety and capacity levels.

The cornerstone of the FAA's new vision of air transportation is a concept known as **"free flight."** Today, aircraft navigate using radio beams. Our airways are a connection of 'radio tubes' through which aircraft under air traffic control (ATC) are routed to their desired destination. A new technology is, however, at hand. Precision navigation using the GPS satellites is now available. With GPS, aircraft will be able to fly direct to their destination airport. The ATC network will monitor the flight of the aircraft and computers on the ground and on-board the aircraft will maintain a 'protection zone' to prevent incursions along the way (see Figure 23). This technique has the potential not only for greater safety, but also for reduced flight times, delays, and fuel consumption.

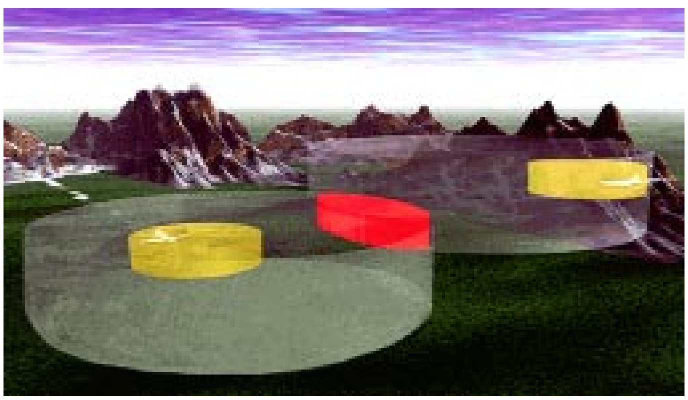


FIGURE 23: In 'free flight" aircraft operate within protected zones (yellow) and alert zones to prevent incursions.

The "free flight" concept allows the pilot the opportunity to select the aircraft's course, speed, and altitude in real time. Free flight will also provide increased flexibility in flight planning and departure time determination. Free flight will radically change the way the air traffic control system works. The difference between today's system and traffic flow management in the future will be the increased extent of collaboration between users and traffic flow management specialists, and the greater flexibility for the users to make decisions to meet their unique operational goals. This concept includes user involvement in the traffic flow management decision making process through an increased sharing of real-time information.

A partnership of the FAA, NASA, DoD, and the aviation industry has made substantial progress in moving the NAS toward the more flexible and efficient concept of free flight. In April 1997, the FAA released the Air Traffic Services Concept of Operations reflecting the user-desired capabilities supporting free flight. In addition, this Government/industry partnership began intensive planning of Flight 2000, a validation and demonstration of these concepts and technologies in the Hawaii and Alaska airspace. The demonstration is slated to begin in 2000. In July 1997, the FAA released the Flight 2000 Initial Program Plan outlining increased safety, services, low-cost avionics, streamlined certification processes, and risk reduction.

SIDEBAR 3: High Tech Sniffing – Advanced Bomb Detection

Detecting explosives in checked or carry-on luggage is the principal means of preventing loss of life due to a terrorist act on an aircraft. Each year more than 500 million Americans board aircraft, carrying more than 1 billion pieces of luggage. Successfully screening for dangerous compounds is, therefore, a great challenge. Detection systems must be highly accurate while minimizing the number of false alarms. They must also be fast to prevent backlogs in busy airports; a special concern as the number of air travelers rises.

Americans have become accustomed to bomb-sniffing dogs patrolling the corridors of airports. The canine nose is a very sensitive molecular detector, able to sense vapors at concentrations three to five orders of magnitude lower than those discernable by humans. Canine operations have been in use since 1972 and have proven especially effective in screening large numbers of bags speedily and at low cost. Terrorists are using more advanced explosives posing a greater challenge to canine patrols. More sophisticated shielding and preparation, and more advanced devices using less explosive material, can limit the effectiveness of canine detection. The bomb that destroyed Pan Am 103 is believed to have been concealed in a tape recorder placed inside a piece of unaccompanied luggage. The device weighed less than 1 pound. Clearly advanced technologies were needed to detect small amounts of highly potent explosives.

The center of excellence related to explosives and weapons detection is the FAA's Aviation Security Laboratory. The Aviation Security Improvement Act of 1990 set ambitious goals for explosives detection equipment. The FAA has been accelerating efforts to overcome the technological challenges associated with explosives detection and finding solutions acceptable to both industry and the traveling public. The result has been a rapidly advancing state-of-the-art and the deployment of initial systems at airports across the country and throughout the world.

FIGURE 24: Advanced X-Ray scanning systems can check more than 1500 bags per hour.

Explosive detection devices come in two forms: bulk detectors and trace element detectors. The most effective devices developed so far are bulk detectors that are enhanced X-ray imaging systems. X-rays pass through a bag and are counted by increasingly more sensitive detectors, allowing measurement of both density and atomic number. This information is compared to profiles of known explosives and an alert is sounded if an dangerous compound is detected. Today these devices are an increasingly common sight. The larger units operate in the baggage handling areas of airports and can accept a large throughput of checked luggage (see Figure 24). They can detect both explosives and weapons. Trace detection devices "sniff" people, luggage, and hand-held items for chemical particles used in explosives. Known as vapor detection technology, these high-tech sniffers simply are advanced forms of the canine nose.

In the future, the detection of explosives and weapons will rely on even more advanced technologies. Passive millimeter wave imaging is one such example, measuring electromagnetic rays emitted by the body and items, both plastic and metal, surrounding it. Magnetic gradient imaging can detect minute variations in field strength due to the presence of ferromagnetic material, such as guns or knives. Nuclear quadrupole resonance techniques rely on measurements of the nuclear signature of explosive materials. Another technique, thermal neutron analysis (see Figure 25), baths items on luggage in low-energy neutrons and searches for the telltale gamma rays then emitted by explosive materials.

These and a host of other advanced techniques are being rapidly developed at government and private sector laboratories. It is likely that no single technology can be relied upon to eliminate the threat of explosives being placed aboard aircraft or at airports. Instead a suite of advanced systems will work in concert to ensure the security of air travelers.

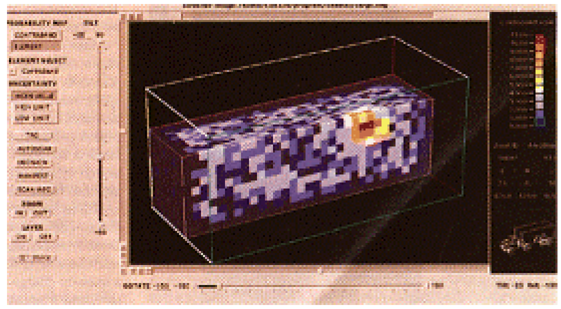


FIGURE 25: Identification of explosive materials in baggage container using thermal neutron analysis.

APPENDIX A: WHCASS GOALS AND SUBGOALS

The White House Commission on Aviation Safety and Security issued a comprehensive set or recommendations aimed at helping Federal agencies establish near- and long-range plans for improving the performance of the air transportation system. The Commission recognized that many of the recommendations required immediate action while others required a significant investment in developing new solutions and advanced technology. The subset of the recommendation listed below that required R&D investment are the subject of this report and are highlighted in **bold face** type.

Goal One: Improving Aviation Safety

1.1 Government and industry should establish a national goal to reduce the aviation fatal accident rate by a factor of five within ten years and conduct safety research to support that goal.

1.2. The FAA should develop standards for continuous safety improvement, and should target its regulatory resources based on performance against those standards.

1.3 The DOT and the FAA should be more vigorous in the application of high standards for certification of aviation businesses.

1.4. The Federal Aviation Regulations (FARs) should be simplified and, as appropriate, rewritten as plain English, performance-based regulations.

1.5. Cost alone should not become dispositive in deciding aviation safety and security rulemaking issues.

1.6. Government and industry aviation safety research should emphasize human factors and training.

1.7. Enhanced ground proximity warning systems should be installed in all commercial and military passenger aircraft.

1.8. The FAA should work with the aviation community to develop and protect the integrity of standard safety databases that can be shared in accident prevention programs.

1.9. In cooperation with airlines and manufacturers, the FAA's Aging Aircraft program should be expanded to cover non-structural systems.

1.10. The FAA should develop better quantitative models and analytic techniques to inform management decision-making.

1.11. The DOT should work with the Department of Justice to ensure that airline crew members performing their duties are protected from passenger misconduct.

1.12. Legislation should be enacted to protect aviation industry employees who report safety or security violations.

1.13. The FAA should eliminate the exemptions in the Federal Aviation Regulations that allow passengers under the age of two to travel without the benefit of FAA-approved restraints.

1.14. The Commission commends the joint government-industry initiative to equip the cargo holds of all passenger aircraft with smoke detectors, and urges expeditious implementation of the rules and other steps necessary to achieve the goal of both detection and suppression in all cargo holds.

Goal 2: Making Air Traffic Control Safer and More Efficient

2.1. The FAA should develop a revised NAS modernization plan within six months that will set a goal of the modernized system being fully operational nationwide by the year 2005; and the Congress, the Administration, and users should develop innovative means of financing this acceleration.

2.2. The FAA should develop plans to ensure that operational and airport capacity needs are integrated into the modernization of the NAS.
2.3. The FAA should explore innovative means to accelerate the installation of advanced avionics in general aviation aircraft.
2.4. The U.S. government should ensure the accuracy, availability and reliability of the GPS system to accelerate its use in NAS modernization and to encourage its acceptance as an international standard for aviation.
2.5. The users of the NAS should fund its development and operation.
2.6. The FAA should identify and justify by July 1997 the frequency spectrum necessary for the transition to a modernized air traffic control system.

Goal Three: Improving Security for Travelers

3.1. The federal government should consider aviation security as a national security issue, and provide substantial funding for capital improvements.
3.2. The FAA should establish federally mandated standards for security enhancements.
3.3. The Postal Service should advise customers that all packages weighing over 16 ounces will be subject to examination for explosives and other threat objects in order to move by air.
3.4. Current law should be amended to clarify the U.S. Customs Service's authority to search outbound international mail.
3.5. The FAA should implement a comprehensive plan to address the threat of explosives and other threat objects in cargo and work with industry to develop new initiatives in this area.
3.6. The FAA should establish a security system that will provide a high level of protection for all aviation information systems.
3.7. The FAA should work with airlines and airport consortia to ensure that all passengers are positively identified and subjected to security procedures before they board aircraft.
3.8. Submit a proposed resolution, through the U.S. Representative, that the International Civil Aviation Organization begin a program to verify and improve compliance with international security standards.
3.9. Assess the possible use of chemical and biological weapons as tools of terrorism.
3.10. The FAA should work with industry to develop a national program to increase the professionalism of the aviation security workforce, including screening personnel.
3.11 Access to airport controlled areas must be secured and the physical security of aircraft must be ensured.
3.12. Establish consortia at all commercial airports to implement enhancements to aviation safety and security.
3.13. Conduct airport vulnerability assessments and develop action plans.
3.14. Require criminal background checks and FBI fingerprint checks for all screeners, and all airport and airline employees with access to secure areas.
3.15 Deploy existing technology.
3.16. Establish a joint government-industry research and development program.
3.18. Significantly expand the use of bomb-sniffing dogs.
3.19. Complement technology with automated passenger profiling.
3.20. Certify screening companies and improve screener performance.
3.21. Aggressively test existing security systems.
3.22. Use the Customs Service to enhance security.
3.23. Give properly cleared airline and airport security personnel access to the classified information they need to know.
3.24. Begin implementation of full bag-passenger match.
3.25. Provide more compassionate and effective assistance to families of victims.
3.26. Improve passenger manifests.

3.27. Significantly increase the number of FBI agents assigned to counterterrorism investigations, to improve intelligence, and to crisis response.
3.28. Provide anti-terrorism assistance in the form of airport security training to countries where there are airports served by airlines flying to the US.
3.29. Resolve outstanding issues relating to explosive taggants and require their use.
3.30. Provide regular, comprehensive explosives detection training programs for foreign, federal, state, and local law enforcement, as well as FAA and airline personnel.
3.31. Create a central clearinghouse within government to provide information on explosives crime.

Goal Four: Responding to Aviation Disasters

4.1. The National Transportation Safety Board (NTSB) should finalize by April, 1997, its coordinated federal response plan to aviation disasters, and Congress should provide the NTSB with increased funding to address its new responsibilities.
4.2. The Department of Transportation should coordinate the development of plans for responding to aviation disasters involving civilians on government aircraft.
4.3. The Department of Transportation and the NTSB should implement key provisions of the Aviation Disaster Family Assistance Act of 1996 by March 31, 1997.
4.4. The United States Government should ensure that family members of victims of international aviation disasters receive just compensation and equitable treatment through the application of federal laws and international treaties.
4.5 Provisions should be made to ensure the availability of funding for extraordinary costs associated with accident response.
4.6. Federal agencies should establish peer support programs to assist rescue, investigative, law enforcement, counseling and other personnel involved in aviation disaster response.

APPENDIX B: REPRINT OF GIBBONS-RAINES MEMORANDUM TO FAA, NASA, AND DoD

THE WHITE HOUSE

WASHINGTON

JUN 26 1997

MEMORANDUM FOR THE SECRETARY OF DEFENSE
THE SECRETARY OF TRANSPORTATION
THE ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FROM: JOHN H. GIBBONS, ASSISTANT TO THE PRESIDENT FOR SCIENCE AND TECHNOLOGY
FRANKLIN D. RAINES, DIRECTOR OF THE OFFICE OF MANAGEMENT AND BUDGET

SUBJECT: Implementation Plan for White House Commission on Aviation Safety and Security Recommendations

The White House Commission on Aviation Safety and Security, which was chaired by the Vice President, submitted its Final Report to the President on February 12, 1997. A number of the Commission's recommendations will have important implications for science and technology planning within the Federal government. To more clearly define these implications, and in support of the FY 1999 budget process, we request that your agencies work together to develop a joint implementation plan for meeting those Commission recommendations that require R&D or technology implementation. The list attached to this memorandum comprises the main recommendations that have implications for science and technology planning.

The implementation plan should include:

1. A narrative description of agency roles and responsibilities summarizing how DoD, DoT and NASA will coordinate their R&D investments for meeting each of the listed recommendations to maximize returns and reduce overlap;
2. A coordinated strategy for identifying and pursuing partnership opportunities with state and local entities and the private sector; and
3. A five year budget profile identifying how each of the recommendations will be supported, including proposed reprogramming or new requests with offsets from other programs.

Since the method by which we pursue the Commission's goals will be affected by pending Congressional action on financing the FAA through aviation user fees, the implementation plan should address two scenarios: one which assumes enactment of full user fee financing for the FAA and one which assumes no new user fees and only internal reprogramming. Assignment of responsibilities by agency should be consistent with statutory missions and with budget principles established by OMB circulars.

We request that this plan be submitted concurrent with your agency FY 1999 budget submissions. If you have any questions on this request, please feel free to contact us. Alternatively, your staff may contact Mr. Jefferson Hofgard of OSTP (456-6043) or Mr. Steven Isakowitz of OMB (395-3807) for assistance. Program-specific questions, as always, should be directed to the OMB Resource Management Office with responsibility for your programs.

APPENDIX C: FIVE-YEAR FEDERAL BUDGET PLAN FOR AVIATION SAFETY AND SECURITY

C1. Summary

Goal	Subgoal	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	Five Year Sum
		Budget Authority in Millions					
	TOTAL	**722.6**	**735.1**	**735.8**	**717.0**	**600.8**	**3511.2**
1.0: Aviation Safety		**269.9**	**301.2**	**340.8**	**354.3**	**353.9**	**1620.0**
1.1	Reduce Fatal Accident Rate	170.1	176.2	196.2	199.2	200.9	942.6
1.6	Optimized Human Factors & Training	47.9	51.3	61.8	66.0	65.3	292.3
1.7	Ground Proximity Warning	0.0	0.0	0.0	0.0	0.0	0.0
1.8	Integrated Safety Databases	4.1	11.2	10.3	10.7	11.0	47.2
1.9	Aging Aircraft Research	41.6	50.3	55.5	60.2	60.4	268.0
1.10	Quantitative Models and Information Systems	6.2	12.2	17.0	18.2	16.2	69.9
1.13	Infant Restraints	0.0	0.0	0.0	0.0	0.0	0.0
2.0: ATC Modernization		**293.4**	**268.1**	**289.0**	**274.0**	**167.9**	**1292.4**
2.1	Modernization Plan	78.3	157.4	188.7	216.6	142.5	783.5
2.2	Airport Capacity Plans	32.2	19.2	14.3	3.1	3.5	72.2
2.3	General Aviation Avionics	9.5	9.2	9.7	8.0	6.3	42.7
2.4	GPS Performance and Integration	173.4	82.2	76.3	46.3	15.7	394.0
2.6	Spectrum Management	0.0	0.0	0.0	0.0	0.0	0.0
3.0: Aviation Security		**159.3**	**165.8**	**106.0**	**88.7**	**79.0**	**598.8**
3.2	Federal Security Standards	5.8	5.8	8.0	11.6	13.0	44.2
3.5	Threat of Explosives	4.0	5.8	8.0	11.6	13.0	42.4
3.6	Protection of Information Systems	142.6	147.1	82.9	58.6	46.5	477.7
3.7	Positive Passenger Identification	0.0	0.0	0.0	0.0	0.0	0.0
3.9	Chemical/Biological Weapons Threat	0.3	0.3	0.3	0.3	0.3	1.5
3.11	Physical Security	3.0	3.0	3.0	3.0	3.0	15.0
3.15	Deploy Existing Technologies	0.0	0.0	0.0	0.0	0.0	0.0
3.16	Government/ Industry R&D	1.9	1.9	2.1	2.1	2.1	10.1
3.17	SAM Threat	0.2	0.2	0.2	0.2	0.2	1.0
3.18	Bomb-Sniffing Dogs	1.0	1.2	1.0	1.0	0.7	4.9
3.19	Automated Passenger Profiling	0.0	0.0	0.0	0.0	0.0	0.0
3.20	Certification of Screeners	0.5	0.5	0.5	0.3	0.3	2.0
3.29	Explosive Taggants	0.0	0.0	0.0	0.0	0.0	0.0

C2. FAA Five Year Budget Plan

BY WHCASS GOALS

Budget Authority in Millions

Goal	Subgoal		FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
TOTAL FAA			***271.6***	***263.9***	***296.3***	***277.3***	***156.1***
1.0:		**Aviation Safety**	**85.2**	**87.8**	**90.4**	**93.1**	**95.9**
	1.1	Reduce Fatal Accident Rate	**71.7**	**54.6**	**74.3**	**76.4**	**78.7**
	1.6	Optimized Human Factors & Training	**16.6**	**13.9**	**17.0**	**17.5**	**18.0**
	1.7	Ground Proximity Warning	-	-	-	-	-
	1.8	Integrated Safety Databases	-	-	-	-	-
	1.9	Aging Aircraft Research	-	-	-	-	-
	1.10	Quantitative Models and Information Systems	-	-	-	-	-
	1.13	Infant Restraints	-	-	-	-	-
2.0:		**ATC Modernization**	**177.2**	**167.3**	**192.9**	**167.4**	**42.1**
	2.1	Modernization Plan	-	**90.0**	**120.0**	**123.0**	**29.0**
	2.2	Airport Capacity Plans	**7.9**	**0**	**0**	**0**	**0**
	2.3	General Aviation Avionics	**0**	**0**	**1.4**	**3.5**	**2.8**
	2.4	GPS Performance and Integration	**169.3**	**77.3**	**71.5**	**40.9**	**10.3**
	2.6	Spectrum Management	-	-	-	-	-
3.0:		**Aviation Security**	**9.2**	**8.8**	**13.0**	**16.8**	**18.1**
	3.2	Federal Security Standards	**5.8**	**5.8**	**8.0**	**11.6**	**13.0**
	3.5	Threat of Explosives	**4.0**	**5.8**	**8.0**	**11.6**	**13.0**
	3.6	Protection of Information Systems	**0**	**0**	**2.6**	**4.2**	**4.1**
	3.7	Positive Passenger Identification	-	-	-	-	-
	3.9	Chemical/Biological Weapons Threat	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
	3.11	Physical Security	-	-	-	-	-
	3.15	Deploy Existing Technologies	-	-	-	-	-
	3.16	Government/ Industry R&D	**1.9**	**1.9**	**2.1**	**2.1**	**2.1**
	3.17	SAM Threat	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
	3.18	Bomb-Sniffing Dogs	**1.0**	**1.2**	**1.0**	**1.0**	**0.7**
	3.19	Automated Passenger Profiling	-	-	-	-	-
	3.20	Certification of Screeners	**0.5**	**0.5**	**0.5**	**0.3**	**0.3**
	3.29	Explosive Taggants	-	-	-	-	-

C3. NASA Five Year Budget Plan

BY WHCASS GOALS

Goal	Subgoal		FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
			Budget Authority in Millions				
TOTAL NASA			***156.6***	***193.9***	***202.8***	***232.9***	***247.4***
1.0:		**Aviation Safety**	**86.7**	**124.4**	**132.5**	**148.2**	**146.1**
	1.1	Reduce Fatal Accident Rate	**37.4**	**55.7**	**57.9**	**67.8**	**68.2**
	1.6	Optimized Human Factors & Training	**31.3**	**37.4**	**44.8**	**48.5**	**47.3**
	1.7	Ground Proximity Warning	-	-	-	-	-
	1.8	Integrated Safety Databases	**4.1**	**11.2**	**10.3**	**10.7**	**11.0**
	1.9	Aging Aircraft Research	**7.6**	**8.0**	**2.6**	**3.1**	**3.3**
	1.10	Quantitative Models and Information Systems	**6.2**	**12.2**	**17.0**	**18.2**	**16.2**
	1.13	Infant Restraints	-	-	-	-	-
2.0:		**ATC Modernization**	**69.9**	**69.5**	**70.3**	**84.7**	**101.4**
	2.1	Modernization Plan	**41.3**	**46.9**	**54.0**	**83.7**	**101.4**
	2.2	Airport Capacity Plans	**21.6**	**16.6**	**11.3**	**0.0**	**0.0**
	2.3	General Aviation Avionics	**7.0**	**6.0**	**5.0**	**1.0**	**0.0**
	2.4	GPS Performance and Integration	-	-	-	-	-
	2.6	Spectrum Management	-	-	-	-	-
3.0:		**Aviation Security**	-	-	-	-	-
	3.2	Federal Security Standards	-	-	-	-	-
	3.5	Threat of Explosives	-	-	-	-	-
	3.6	Protection of Information Systems	-	-	-	-	-
	3.7	Positive Passenger Identification	-	-	-	-	-
	3.9	Chemical/Biological Weapons Threat	-	-	-	-	-
	3.11	Physical Security	-	-	-	-	-
	3.15	Deploy Existing Technologies	-	-	-	-	-
	3.16	Government/ Industry R&D	-	-	-	-	-
	3.17	SAM Threat	-	-	-	-	-
	3.18	Bomb-Sniffing Dogs	-	-	-	-	-
	3.19	Automated Passenger Profiling	-	-	-	-	-
	3.20	Certification of Screeners	-	-	-	-	-
	3.29	Explosive Taggants	-	-	-	-	-

C4. DoD Five Year Budget Plan

BY WHCASS GOALS

Goal / Subgoal	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
	Budget Authority in Millions				
TOTAL DOD	*286.9*	*289.7*	*226.1*	*191.5*	*180.9*
1.0: Aviation Safety	**95.0**	**108.3**	**116.9**	**112.2**	**111.1**
1.1 Reduce Fatal Accident Rate	61.0	66.0	64.0	55.0	54.0
1.6 Optimized Human Factors & Training	-	-	-	-	-
1.7 Ground Proximity Warning	-	-	-	-	-
1.8 Integrated Safety Databases	-	-	-	-	-
1.9 Aging Aircraft Research	34.0	42.3	52.9	57.2	57.1
1.10 Quantitative Models and Information Systems	-	-	-	-	-
1.13 Infant Restraints	-	-	-	-	-
2.0: ATC Modernization	**46.3**	**31.3**	**25.9**	**21.9**	**24.4**
2.1 Modernization Plan	37.1	20.5	14.7	9.9	12.1
2.2 Airport Capacity Plans	2.7	2.6	3.0	3.1	3.5
2.3 General Aviation Avionics	2.5	3.2	3.3	3.5	3.5
2.4 GPS Performance and Integration	4.1	4.9	4.8	5.4	5.4
2.6 Spectrum Management	-	-	-	-	-
3.0: Aviation Security	**145.6**	**150.1**	**83.3**	**57.4**	**45.4**
3.2 Federal Security Standards	-	-	-	-	-
3.5 Threat of Explosives	0.0	0.0	0.0	0.0	0.0
3.6 Protection of Information Systems	142.6	147.1	80.3	54.4	42.4
3.7 Positive Passenger Identification	-	-	-	-	-
3.9 Chemical/Biological Weapons Threat	0.0	0.0	0.0	0.0	0.0
3.11 Physical Security	3.0	3.0	3.0	3.0	3.0
3.15 Deploy Existing Technologies	-	-	-	-	-
3.16 Government/ Industry R&D	-	-	-	-	-
3.17 SAM Threat	-	-	-	-	-
3.18 Bomb-Sniffing Dogs	-	-	-	-	-
3.19 Automated Passenger Profiling	-	-	-	-	-
3.20 Certification of Screeners	-	-	-	-	-
3.29 Explosive Taggants	-	-	-	-	-